Applications of TOPAZ^{32} Portable Phased Array System for Truly Efficient Inspections

INTRODUCTION

The first generation of portable phased array UT (PA UT) systems has hit the market in the early 2000's. The massive adoption of these devices has been a game-changer for ultrasonic inspections of critical components in oil & gas, aerospace, heavy industry and power generation plants.

Taking advantage of the last ten years of improvements of digital electronics and leveraging on lessons learned from field experience, Zetec has recently developed the TOPAZ^{32} system, which offer much more power and performance. For example, users of this system can now benefit from larger data file size, better amplitude resolution, faster data acquisition rate and advanced on-board data analysis. This opens brand-new possibilities to the non-destructive testing industry for the application of portable PA UT systems.

This paper will show how enhanced computing power and hardware performance of the TOPAZ^{32} system (see Figure 1) allow more powerful on-board software. Various practical examples will be presented to illustrate how this translates into more efficiency in preparation, acquisition, analysis & reporting of a PA UT inspection.

Figure 1: TOPAZ^{32} Portable PA UT System

PREPARATION

Any good UT inspection starts with an adequate preparation. Starting from the geometry and material of the component to be inspected (see Figure 2), the right insonification strategy needs to be established, leading to the inspection method, (conventional UT, TOFD, PA UT or any combination), acoustic beam parameters, probes & wedges to be used, and positioning of the search units to adequately cover the volume of interest. This initial process is usually called scan planning.

Figure 2: On-board Specimen Editor

The graphic processing power of the TOPAZ^{32} allows on-board creation of a 3D representation of the inspected part, including weld profile and heat-affected zone, for mostly flat or cylindrical geometries. This greatly facilitates the creation of an adequate scan plan. Indeed, with the visual feedback provided by the on-board focal law calculator, the optimization of the inspection angles and search unit positioning can be done by simply sliding the representation of the search unit on the representation of the inspected part (see Figure 3). Also, for multi-channel (or multi-group) setups, coverage assessment can be visualized, even when using different inspection methods simultaneously (see Figure 4).

Figure 3: On-board Phased Array Calculator – Single Channel

Figure 4: On-board Phased Array Calculator – Multiple Channels

For non-experts, setting up a TOFD channel on a first-generation portable PA system can be quite complicated. First, you need to manually determine the angle and the probe-center separation (PCS) required to get adequate crossing point of the transmitter and receiver beams. Then, depending of probe frequency, probe diameter, wedge angle and material velocity, you need to make sure the divergence of the acoustic beam will provide adequate coverage of the volume of interest. Finally, you need to manually set the timebase start and range to record the signal from the lateral wave to the first mode conversion, as required by many codes. And this process obviously becomes more tedious when the inspection is performed on a more challenging configuration such as a longitudinal seam weld.

The visual feedback provided by the TOPAZ32 makes TOFD channel creation easy (see Figure 5). By setting the required depth of the crossing point of the transmitter and receiver beams, the PCS is automatically calculated. Moreover, to facilitate the positioning of the probes and wedges on the scanning device, the front-wedge separation is also provided. 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 timebase start and range are automatically applied, simplifying even more the TOFD setup creation.

Figure 5: On-board TOFD Calculator

First adopted on a larger scale in nuclear power plants in the mid-2000's, the use of 2D matrix probes in transmit-receive configurations (or Dual Matrix Arrays) has recently branched out to other markets, particularly in Oil & Gas. This inspection method, especially when using low-frequency LW, has proven its efficiency on highly-attenuating austenitic steel material. Up to now, the only ways to use 2D matrix arrays on portable PA systems was to import focal law files created with an external calculator or to remote-control the system using advanced PC-based software.

The onboard PA calculator of the TOPAZ^{32} allows for calculating focal laws for 2D matrix arrays (see Figure 6). It is therefore possible to define 2D matrix probes, wedges (either pulse-echo or pitch-&-catch, with or without roof angle), beam steering, beam skewing & focusing depth directly from the system's user interface.

Figure 6: On-board 2D Matrix PA Calculator

Another emerging PA UT technique is the compound scanning. Compound scanning is a combination of sectorial and linear scanning processes; the active aperture moves along the axis of the 1D linear probe (just like a linear scan) as the refracted angle sweeps (just like a sectorial scan). The end result can provide a much better coverage than sectorial or linear scanning alone.

Just like for the control of 2D matrix probes, the only ways to perform a compound scan on other portable PA systems is to import focal law files created with an external calculator or to remote-control the system using advanced PC-based software. The onboard PA calculator of the TOPAZ[32] allows for calculating focal laws for compound scanning right from the system's user interface (see Figure 7). It is therefore possible to perform modifications to the focal laws (angles, elements, focusing, etc.) live during setup creation, without having to go back to an external software and without transferring configuration files.

Figure 7: On-board PA Calculator with Compound Scanning Capabilities

ACQUISITION

Data acquisition is often delegated to a less experienced operator. It is therefore primordial that the acquisition unit makes that process as smooth and easy as possible. The high performance of the TOPAZ32 can help mitigating the risk of costly rescans by providing more visual support for the interpretation of PA UT data, by allowing a faster acquisition speed and by offering a better management of sensitivity levels.

Even though the interpretation of the PA UT data is usually the responsibility of the data analyst, the operator in charge of acquisition needs to validate the quality of the signals he is acquiring. Therefore, he needs to have a basic understanding of the signal he sees on the screen while scanning. In addition to the typical A-, B-, C-, D- and S-Scan views, the TOPAZ32 offers volume-corrected on-line merged views (see Figure 8). By displaying information from all the UT beams of one channel in a single Side (B), Top (C) of End (D) view, data interpretation during acquisition is greatly facilitated.

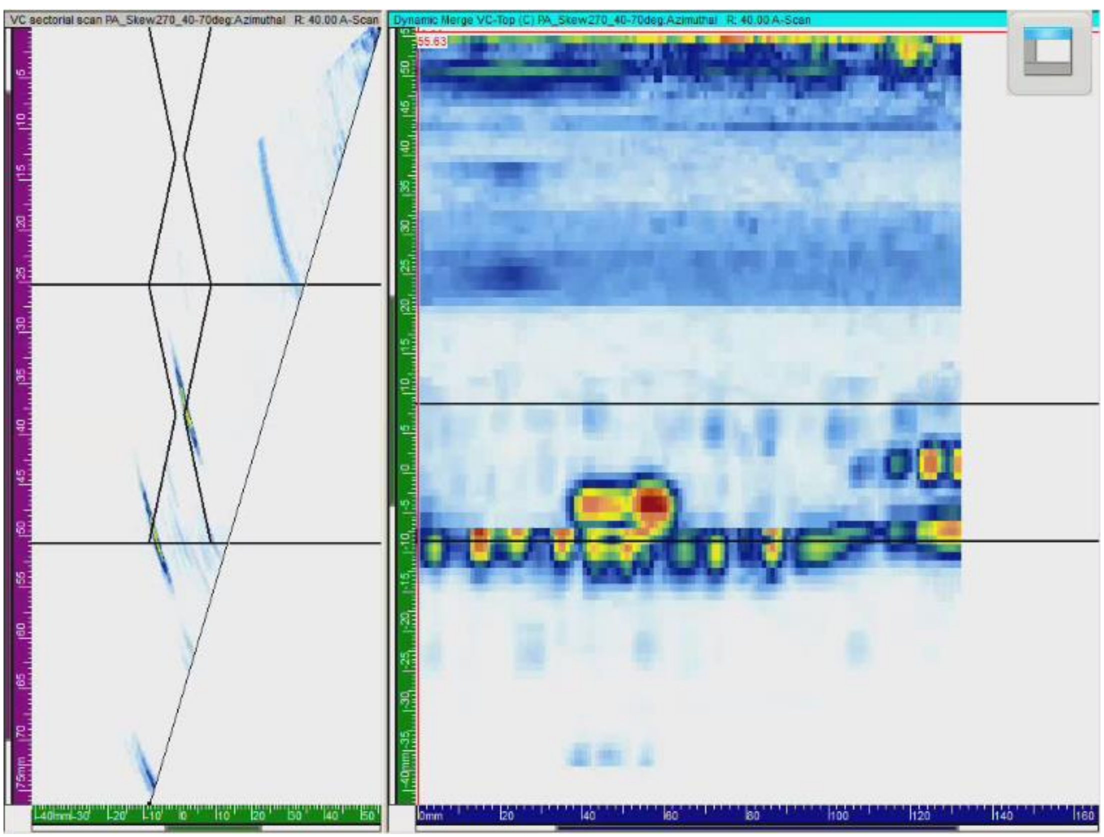


Figure 8: Volume-Corrected On-Line Merged Top View (right)

For any ultrasonic setup, the maximum pulse repetition frequency (PRF) is limited either by the acoustic properties (sound velocity, time base range, number of acoustic beams, etc.) or by the maximum data recording rate of the hardware. Of course, it is impossible to modify the physics of sound. However, the improvements of computing capabilities allow the TOPAZ^{32} to write data faster in memory: 10 MB/s compared to 6.1 MB/s for first-generation systems. For setups with relatively small time base range, these improved performances directly reflect on the maximum PRF and allow typically 65% faster data acquisition.

The TOPAZ^{32} allows efficient acquisition of data encoded on up to 16 bits. The high amplitude resolution provided by 16-bit data allows the efficient use of software gain. This tool can be seen as a zooming function on the amplitude scale. It allows applying or removing gain by a simple software process either on-line or in post-acquisition data analysis. A common practice for weld inspection using first-generation portable PA systems involves performing two scans: one with high gain to allow easy detection, and another with lower gain to avoid saturation for amplitude-drop sizing. With the efficient use of software gain provided by the 16-bit data resolution of the TOPAZ^{32}, only one scan is required for detection and sizing. Figure 9 shows detection of a planar (lack of side-wall fusion) and volumetric (cluster porosity) indication in a single data file. During acquisition, the hardware gain level was low enough to avoid saturation of the specular reflection of the planar indication. Still, by using software gain, the volumetric indication is clearly detected.

Data storage media have also significantly evolved in the last few years. The solid-state drives (SSD) in particular are now a great option for portable PA systems. Since these drives do not have any mobile parts, they prove to be very rugged yet provide large data storage capacity and fast read/write access. The TOPAZ^{32} is equipped with 128 GB SSD, allowing for convenient data management. This also allows for acquiring larger data files. While first-generation PA systems were usually limited to 160 or 300 MB, the TOPAZ^{32} can acquire files up to 2 GB and still offer convenient on-board data analysis capabilities.

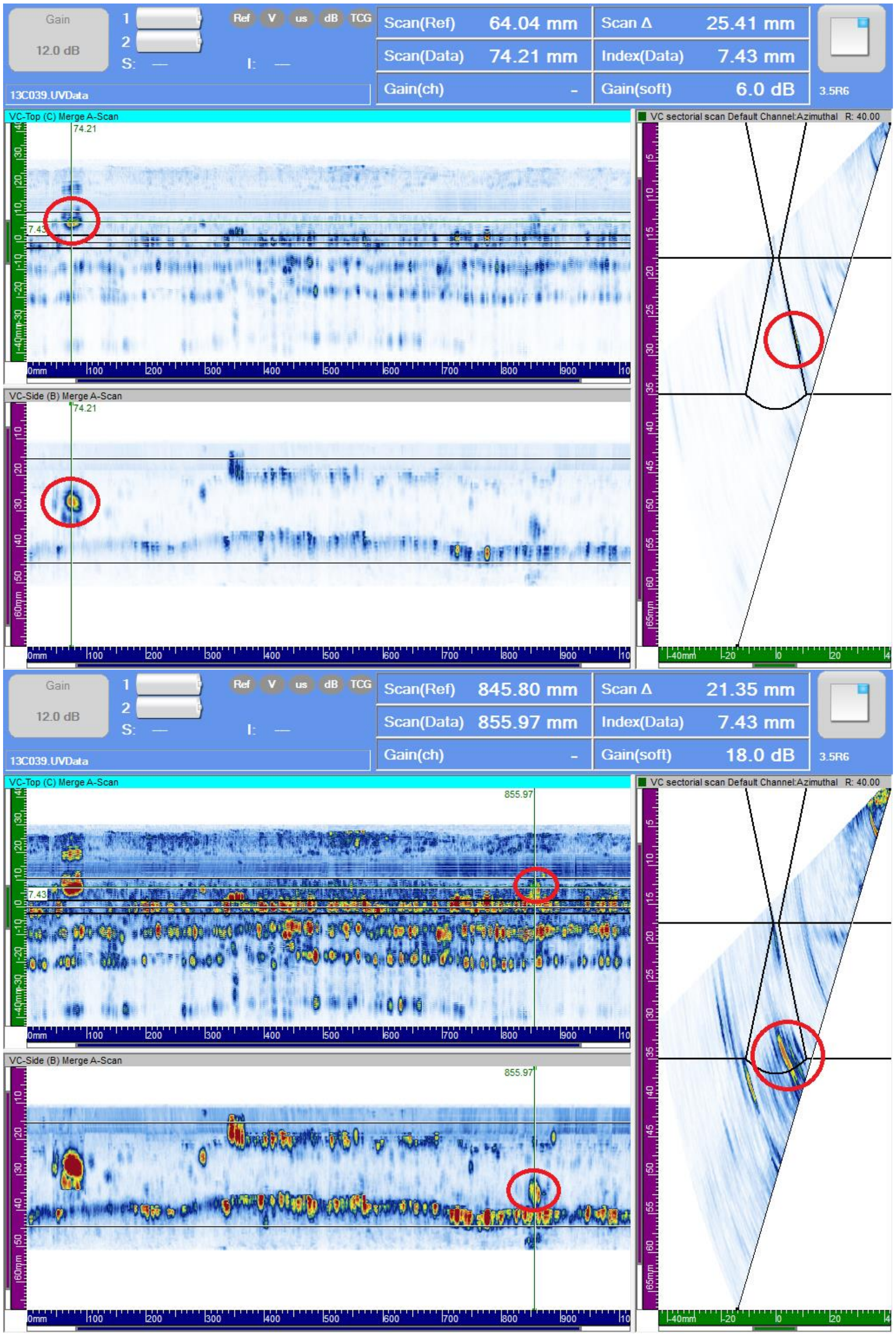


Figure 9: Efficient use of software gain on planar (above) and volumetric (below) indications

ANALYSIS

The TOPAZ^{32} is equipped with high-performance yet low-consumption processors and high-resolution multi-touch display. This improved computing power and user interface allow performing on the TOPAZ^{32} analysis operations which could only be made on advanced analysis software before.

Every experienced data analyst has his own preferences for data analysis display layouts. The lack of customizability of the display layout on first-generation portable PA systems made data analysis tedious to perform on-board. The TOPAZ^{32} offers the same level of customization of the display layout as advanced PC-based analysis software. Data analysts can create, save and load custom layouts with no limitation, other than the size of the screen, on the number of channels (or groups) displayed.

High-performance processors and extended RAM memory of the TOPAZ^{32} allow performing on-board volumetric merge. This operation could only be made on advanced analysis software before. Data merging combines in a single group data coming from multiple acoustic beams, which greatly facilitates the interpretation of PA UT data (see Figure 10).

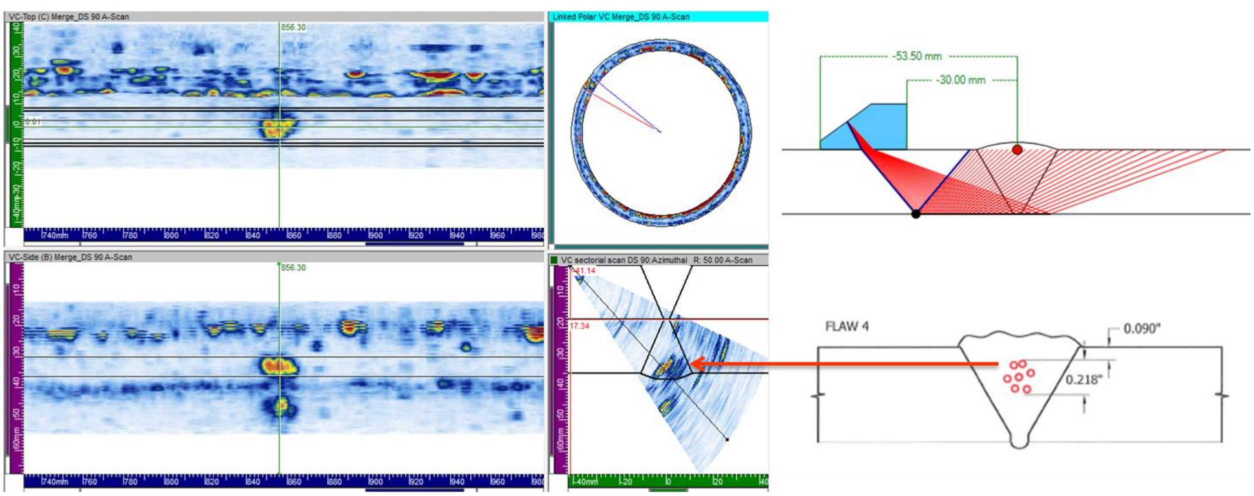
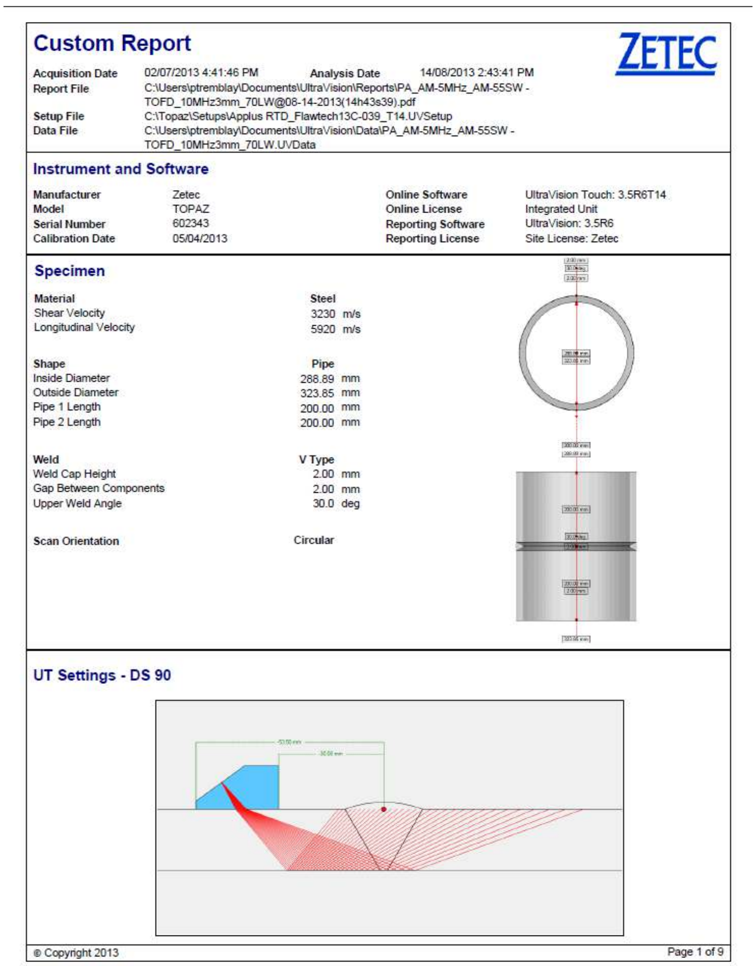


Figure 10: Volumetric Merge on Cluster Porosity

REPORTING

For most customers, the reports are usually what they are paying inspection vendors for. Even though this is not the most value-added part of the inspection process, reporting is nonetheless a key task as reports are the reflection of the professionalism of the inspection vendors.

As it is based on an up-to-date operating system, the TOPAZ32 can generate 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 (see Figure 11). By providing a meaningful report by the click of a button, the TOPAZ32 helps keeping the post-inspection paperwork to the bare minimum.


Custom Report

ZETEC

Acquisition Date	02/07/2013 4:41:46 PM	Analysis Date	14/08/2013 2:43:41 PM
Report File	C:\Users\ptremblay\Documents\UltraVision\Reports\PA_AM-5MHz_AM-55SW - TOFD_10MHz3mm_70LW@08-14-2013(14h43s39).pdf		
Setup File	C:\Topaz\Setups\Applus RTD_Flawtech13C-039_T14.UVSetup		
Data File	C:\Users\ptremblay\Documents\UltraVision\Data\PA_AM-5MHz_AM-55SW - TOFD_10MHz3mm_70LW.UVData		

Instrument and Software

Manufacturer	Zetec	Online Software	UltraVision Touch: 3.5R6T14
Model	TOPAZ	Online License	Integrated Unit
Serial Number	602343	Reporting Software	UltraVision: 3.5R6
Calibration Date	05/04/2013	Reporting License	Site License: Zetec

Specimen

Material	Steel
Shear Velocity	3230 m/s
Longitudinal Velocity	5920 m/s
Shape	Pipe
Inside Diameter	288.89 mm
Outside Diameter	323.85 mm
Pipe 1 Length	200.00 mm
Pipe 2 Length	200.00 mm
Weld	V Type
Weld Cap Height	2.00 mm
Gap Between Components	2.00 mm
Upper Weld Angle	30.0 deg
Scan Orientation	Circular

UT Settings - DS 90

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Figure 11: Custom Inspection Report

SOFTWARE COMPATIBILITY

Since the performance of the on-board processors and operating system of the TOPAZ^{32} are similar to those of a standard PC, its on-board UT software is using exactly the same engine as UltraVision 3, but with an adapted user interface. Therefore, this provides full compatibility for setup files and data files.

Even though the TOPAZ^{32} has been designed to work in full autonomy, setups can be created using UltraVision 3, with all the extra features it has to offer. For example, when the use of more complex probe configurations is required (annular, flexible or custom arrays), setup creation can be done on UltraVision 3 and then loaded into the TOPAZ^{32} through a USB memory stick. As the setup file format is the same for both platforms, the operation is seamless. This allows more flexibility to tackle the most challenging applications.

The same concept also applies to data files. When more advanced analysis features – such as 3D visualization of UT data – is required, or just for more comfort provided by larger PC monitors, data files can be transferred to UltraVision 3. As the data file format is the same for both platforms, the operation does not require the use of converter.

In addition, it is also possible to perform data acquisition by remotely driving the TOPAZ^{32} by UltraVision 3 through an Ethernet connection. Since data are saved on the PC's hard disk, the maximum data file size then becomes 20 GB instead of 2 GB.

CONCLUSIONS

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

1. The enhanced computing power of the TOPAZ^{32} allows improved efficiency for:
    a. Setup preparation by providing visual feedback of focal laws, including 2D matrix, compound scanning and TOFD configurations;
    b. Data acquisition by providing more visual support for the interpretation of PA UT data, by allowing a faster acquisition speed and by offering a better management of sensitivity levels;
    c. Data analysis by allowing creation of custom display layouts and by offering on-board volumetric merge;
    d. Reporting by generating ready-to-print customizable PDF reports.
2. Even though the TOPAZ^{32} has been designed to work in full autonomy, it still provides full compatibility with UltraVision 3 allowing more flexibility to tackle the most challenging applications.