

Field examples from an acoustic casing inspection tool

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SUMMARY

Acoustic televewers are routinely used in open holes to scan the borehole wall, using a focused acoustic beam. The resulting acoustic reflections are processed for amplitude and first arrival times. This information, combined with azimuth and tilt data, can provide high-resolution caliper measurements and determine formation hardness and orientation of fractures and bedding planes. New hardware allows downhole processing of the acoustic reflections to allow logging of open holes through centered PVC (synthetic plastic material) casing. Further application of this new downhole signal processing has now been applied to inspection of steel casing. Details of this processing and examples from both models and field case studies show that this tool can be used in a wide variety of casings to determine total thickness and loss from both inside and outside corrosion.

INTRODUCTION

Acoustic televewers have been in use for several decades and have been primarily used to determine fracture and bedding plane orientation. More recently, stress field orientation and breakout analysis has been developed using data from such devices. Modern digital tools are capable of recording full waveforms of the acoustic reflection, providing access to more information. Extremely high data rates have prompted tool designers to move some processing downhole, to allow faster logging speeds and real-time signal processing (Deltombe and Schepers, 2004). Two acoustic televewers using this new architecture are now available on the market : ABI40 (40mm diameter, 1.8m long) for low temperatures (125°C) and low pressure (50Mpa) logging and ABI85 (85mm diameter, 3.7m long) for high temperature (275°C) and high pressure (120Mpa) applications. Recently, the processing capabilities of the ABI acoustic televewer system has been upgraded to allow downhole isolation and processing of the multiple reflections which occur across steel casing (Deltombe & al., 2004). This tool uses specialized processing algorithms to provide real time thickness and inside/outside caliper information for steel casing. This information is used to evaluate the mechanical competence of steel casings used in oil and gas production as well as water wells.

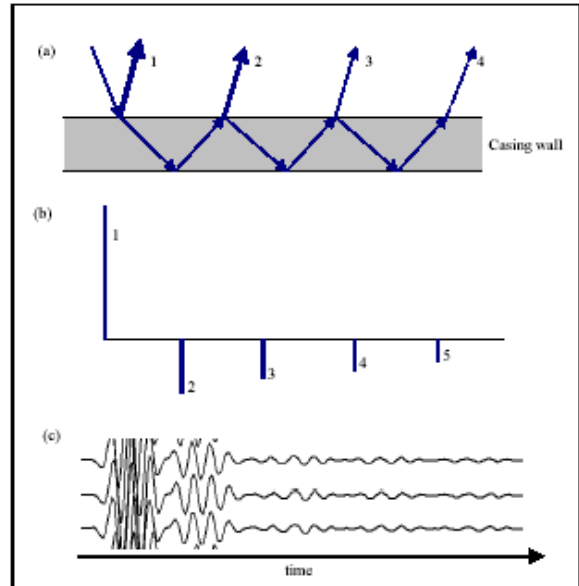


Figure 1 : Acoustic response of casing wall. (a) Travel path of acoustic wave, (b) unit impulse response of acoustic casing wall model, (c) real acoustic signal recorded with ABI40.

ACOUSTIC TELEVIEWER METHOD

The acoustic televewer scans the borehole at up to 288 times per revolution. For casing inspection a scan rate of 72 times per revolution is normally used. The resulting reflection from the 1.2 MHz transducer impulses is recorded for each firing.

The signal is digitized into tool memory with a sample interval of 0.1 microseconds. The maximum number of sample points is 4096. A parallel DSP (digital signal processor) processes this signal in real time

Most of the acoustic energy is reflected back from the inner surface of the steel casing (see Figure 1a, ray path 1). Only 10-15% of the energy is transmitted into the casing wall. As in conventional acoustic televewer logging, the travel-time and amplitude of the inner casing signal is measured and transmitted to the surface. The remaining acoustic energy from the impulse is reflected back from the outside wall of the casing (see Figure 1 a, ray path 2). This energy is trapped within this high impedance acoustic layer. After the primary reflections, a number of relatively strong multiples are produced within the casing walls, with decreasing amplitudes due to leakage of energy. Figure 1 c shows an example of a real acoustic signal recorded with in casing with an 11 mm thickness. The dominant wavelength is in the 5-6

mm range, so the casing wall has to be considered as a thin layer. The fact that the inner and outer casing signals overlap, and the additional noise seen in this real waveform make the determination of the outer casing wall travel time much more difficult to measure. However, by taking into consideration the redundant information in the multiples, the precision of the outer casing travel time can be greatly improved (Schepers, 1983). Taking into account the dynamic range of the acoustic system, the speed of the downhole DSP, and the data window chosen, it is possible to measure the thickness of 11 mm casing to within 1 mm precision. This is within the API allowable variation of 12.5% for axing thickness.

The measurement of the casing thickness is part of the solution. To be effective, casing inspection must be able to determine whether the reduction comes from inside or outside the casing. To accomplish this end, a method for further processing the data within the measurement window is applied. Basically, a total of the amplitudes of the inner and outer primary reflections and all multiples are measured. If this value is high, then the thickness estimate is more reliable. This measurement is called thickness amplitude. By applying a set of processing rules, two cases can be determined.

1. The related reflection amplitude (amplitude 1) from the inner surface is not considerably different from the mean amplitude where the related thickness amplitude is above a certain minimum level.
2. The related reflection amplitude (amplitude 1) from the inner surface is low with respect to the noise level of the system.

In the first case, we infer that there are defects at the outside of the casing; the second case indicates defects at the inside of the casing. In both cases, the thickness amplitude helps to identify defects even if the exact casing thickness can't be determined.

LABORATORY MEASUREMENTS

To evaluate the methods, laboratory samples were prepared with different man-made defects and the samples were logged with the standard tool, using the appropriate centralizers to maximize signal strength and coherency. Table 1 is a summary of the defects logged.

Table 1 Summary of casing samples and defects

Test	Travel time	ID (mm)	ID (in)	Thickness (mm)	OD (in)
8	180	189.48	7.46	11	8.33
12	263	312.32	12.30	11	13.16
15	306	375.96	14.8	12	15.75

Test	Scan Steps	Sample interval	Defect (mm)	Pixel Per Defect	Pixels Between Defect
8	72	8.27	30	3.6	1.2
12	72	13.63	30	2.2	0.7
15	72	16.40	30	1.8	0.6

Examples data for the 8-inch casing sample are shown in Figure 2. A schematic drawing of the defects is shown in figure 2 c. The numbers to the left of the defects correspond to the remaining casing thickness in the sample. Photographs of the outside of the casing are shown in figure 2 b. Different textures are seen between the upper and lower defects. The measured thickness travel time is shown in figure 2 a. The larger defects are very well identified by the log data. These areas are 45 x 45 mm, separated by 25 mm. The two smaller 20 X 20 mm defects are detected but not separated.

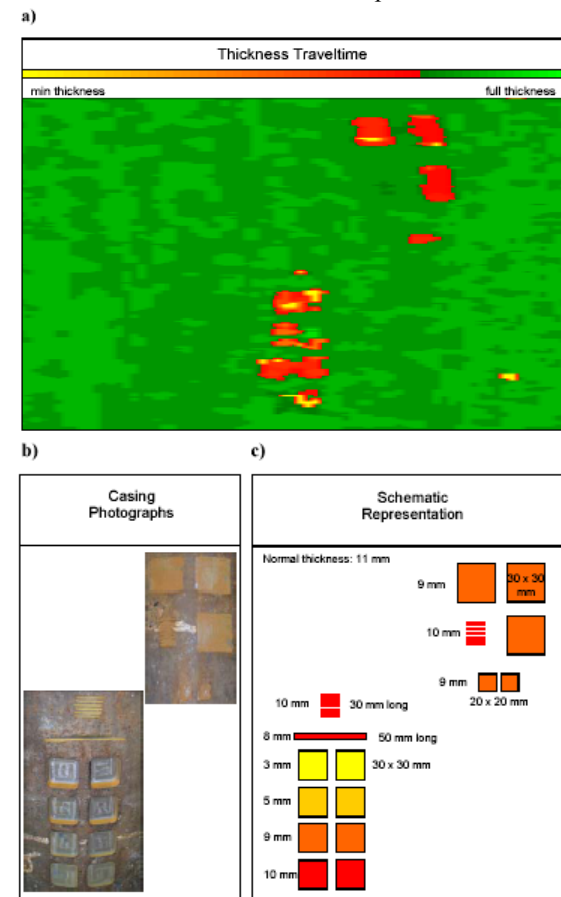


Figure 2. Casing thickness measurement in a 8-inch casing. a) Display of the on-line calculated casing thickness, b) Photos of the casing thickness reductions (defects) on the outside of the casing, c) Description of the defects.

The results for the 12-inch casing are shown in figure 3 and for the 15" casing, in figure 4.

The defects of the 12-inch casing are the same as the defects in the lower part of the 8 inch casing. The thickness travel time seen to the right of the defect area is represented by a dark green band, changing to red at the bottom. This indicates that the casing thickness is reduced in this area. These correlate well with the yellow areas of the inner casing) image (fig 3 d), which means that the casing thickness variation is mainly on the inner wall.

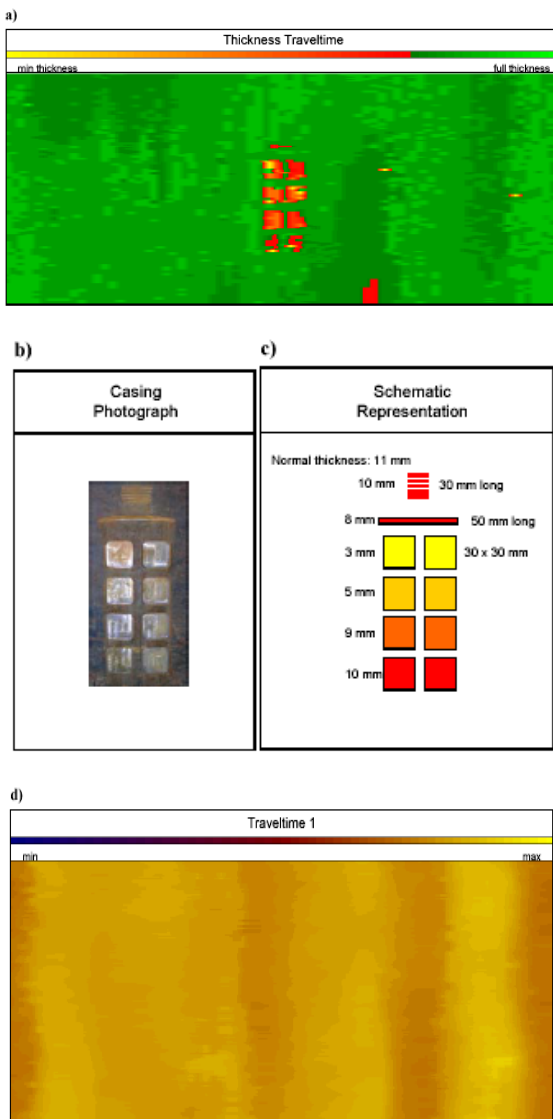


Figure 3. Casing thickness measurement in a 12-inch casing. a) Display of the on-line calculated casing thickness, b) Photos of the casing thickness reductions

(defects) on the outside of the casing, c) Description of the defects.

The 15-inch casing has the same defects, and the defects are seen nicely. The photograph shows corrosion on the inside of this sample (right side of photo) (figure 4). Combined processing of thickness travel time, thickness amplitude, and inner casing amplitude has detected areas of considerable inner corrosion where no thickness travel time could have been measured. The corroded areas are clearly seen in the inner amplitude.

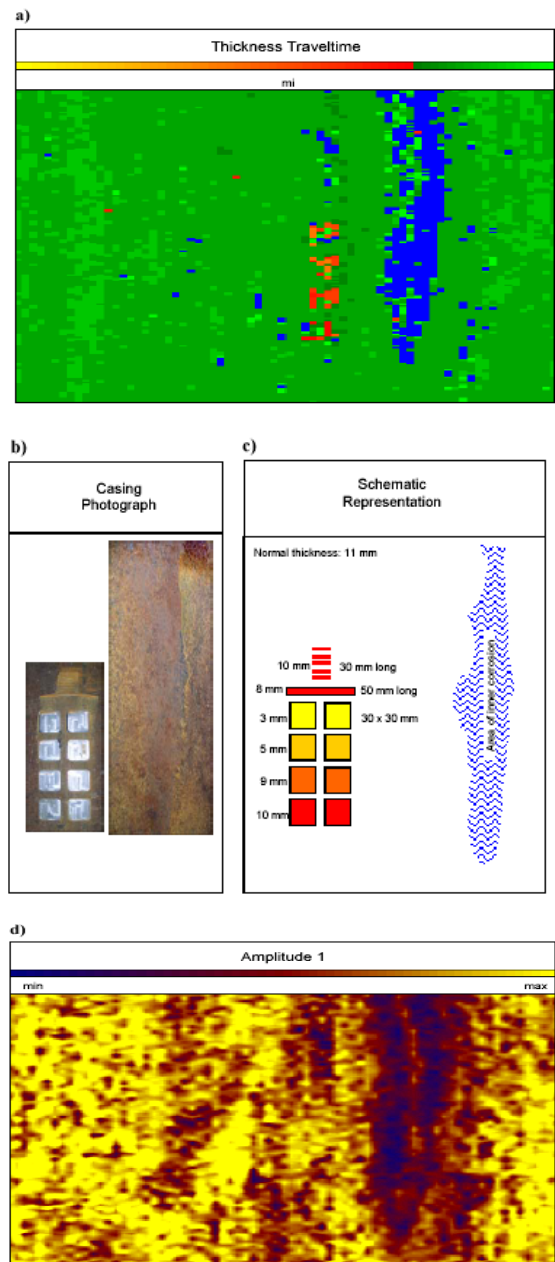


Figure 4. Casing thickness measurement in a 15-inch casing. a) Display of the on-line calculated casing thickness, b) Photos of the casing thickness reductions

Figure 4. Casing thickness measurement in a 15-inch casing. a) Display of the on-line calculated casing thickness, b) Photos of the casing thickness reductions (defects) on the outside of the casing, c) Description of the defects.

FIELD CASE STUDIES

Example 1

Measurements were made in a cased hole, which has a perforated section. As a result of the perforation, the casing has been damaged. Figure 5 shows the processed data, indicating a crack in the casing and deformation of 3 mm. The crack as well as the perforation holes are not only visible on the Inner Amplitude image but also on the Thickness image and the Score image even if at these casing defects no casing thickness is defined. The grey shaded area between the Inner Radius and Outer Radius curves corresponds to a vertical cross-section of the casing well. Where the casing is deformed a small change in thickness can be observed.

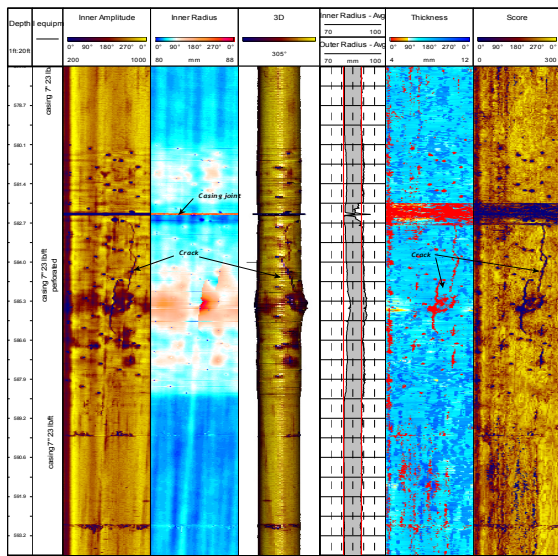


Figure 5. Casing deformation and casing thickness determination along a perforated casing section.

Example 2

Results of logging in a 20" welded casing are displayed in Figure 6. The welding joints are visible as dipping lines in all images. No casing thickness (white values) could be measured along the welding joints.

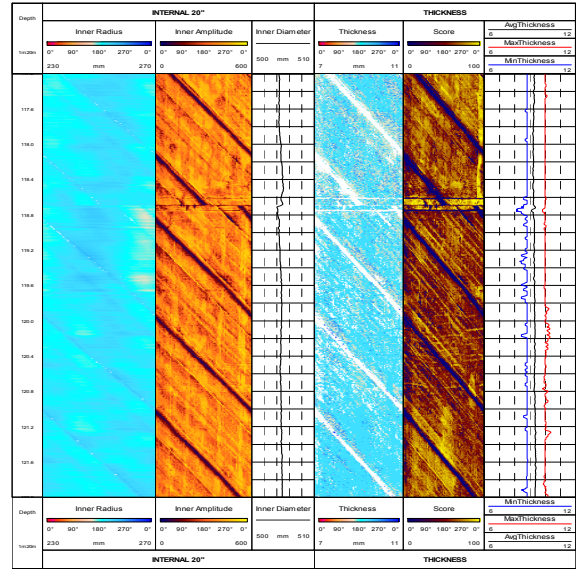


Figure 6. Caliper and casing thickness variation of a welded casing.

Example 3

A severe casing deformation could be identified in this 12" $\frac{3}{4}$ cased well. Data are displayed in Figure 7 and the shape of the deformation can be well visualized in the 3D view. The degree of deformation can be estimated from the Caliper-max and Caliper-min curves.

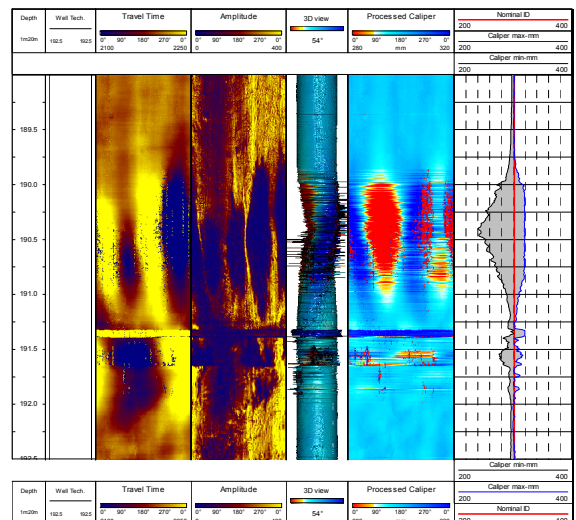


Figure 7. Detection of a severe deformation of a casing pipe.

Example 4

Figure 8 shows nicely a succession of pipes and casing collars. Furthermore, a different section in casing type and thickness could be highlighted. The difference in thickness can be estimated to be 2.4mm by looking at the Inner Radius and Thickness curves.

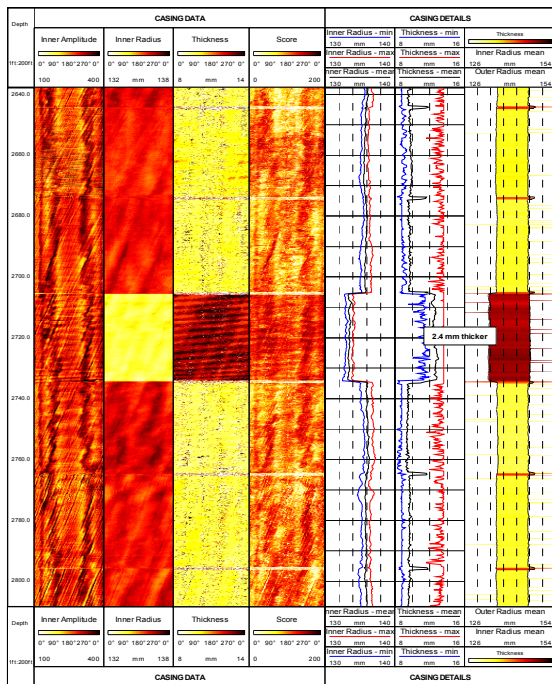


Figure 8. Verification of different pipes in a cased borehole.

ACKNOWLEDGEMENTS

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CONCLUSIONS

Additional field-testing is being carried out by both the tool developers and their customers. This new data will be used to fine-tune the capabilities of the measurement and the processed results. Four service companies are currently using the new tool and additional data will be presented as it becomes available. The initial results indicate that ABI acoustic televiewer with downhole DSP capabilities is well suited for high resolution casing inspection surveys.

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