New crack-sizing technology increases accuracy by removing depth limits

by Rogelio Jesus Guajardo, Global Manager Data Analysis UC, NDT Global, Germany

NDT Global is pushing the boundaries in ILI crack-sizing technology, using high-resolution robots to gather data for its enhanced sizing methodology to provide sizing for features greater than 4 mm. The ICE methodology is combined with a new depth-sizing algorithm to extend the inspection range over the full wall thickness.

Crack inspection of pipelines by robots using conventional ultrasonic shear wave technology has become a standard for inline inspection (ILI) of liquid pipelines.

These robots have proven very successful at detection of various types of cracks or crack-like anomalies. Because most cracks or crack-like defects in pipelines are axially oriented, the first NDT Global ultrasonic crack (UC) inspection robots were developed for axial crack inspection.

In comparison to circumferential cracks, axial cracking shows a significant threat to the pipeline due to hoop stress. Cracks, crack-like anomalies or linear anomalies can appear in the base material or in the longitudinal weld.

The last one is the greatest threat because this is the weakest area in the pipeline. Axial anomalies in the long seam have different causes, such as fatigue and manufacturing anomalies.

Absolute depth sizing for crack inspections was introduced around 2013, with the limitation that features greater than 4 mm could not be sized. Technology improvements, especially the introduction of high-resolution (UCx) robots have allowed new methodologies to remove this limitation and size the depth of the features for the full range.

HIGH-RESOLUTION ROBOTS

In general, the resolution of an ultrasonic ILI tool is produced by four components:

- Axial resolution is the axial distance between two consecutive measurements of the ultrasonic sensors.
- Circumferential resolution is the circumferential distance between two adjacent ultrasonic sensors. Both axial and circumferential resolution determine the scanning grid.
- Sampling frequency of analogue-to-digital converters (ADC) determines the resolution of the time-of-flight measurement of ultrasonic indications as well as the maximum amplitude error of the peak amplitude measurement.

Circumferential resolution	No. of Features	Depth range
Standard	360	1 mm ... 5 mm with 1 mm steps
High resolution	2250	1 mm ... 5 mm with 1 mm steps

TABLE 1: Loop test details from the standard and high-resolution inspections.

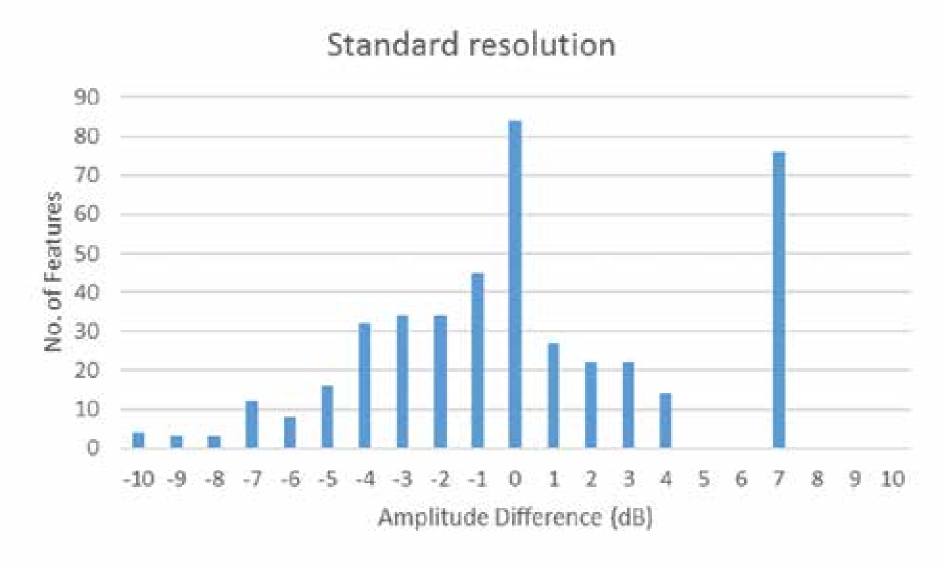

FIGURE 1: Standard resolution loop test results, 49 per cent within ±2 dB.

» Sampling depth of ADC determines the resolution of the amplitude measurement of ultrasonic indications. It also relates to the dynamic amplitude range that can be covered.

UC robots have a standard circumferential resolution of 10 mm. In comparison, UCx robots have a 5 mm circumferential resolution.

The resolution increase provided by twice the number of sensors has two highly useful effects: first, it reduces measurement dispersion by having more sensors scanning the same area, and second, it increases the probability of having one sensor in the optimal position in relation to the feature.

Tests proved the increase of the circumferential resolution reduced the dispersion of the measurement. Using NDT Global's testing facilities in Stutensee, Germany allowed the comparison between standard and high-resolution inspections.

During the comparison, a threshold of ±2 dB was established between the designed depth and the measured depth.

Figure 1 displays the results from the standard resolution, where 0 dB on the X axis represents the amplitude expected to calculate the designed depth. Standard robots show 49 per cent of the measurements within ±2 dB.

Figure 2 shows the result of the high-resolution loop tests. The chart shows a homogeneous bell curve where 85 per cent of the results are within the established threshold of ±2 dB. Standard resolution required a threshold of ±6 dB to achieve 80 per cent.

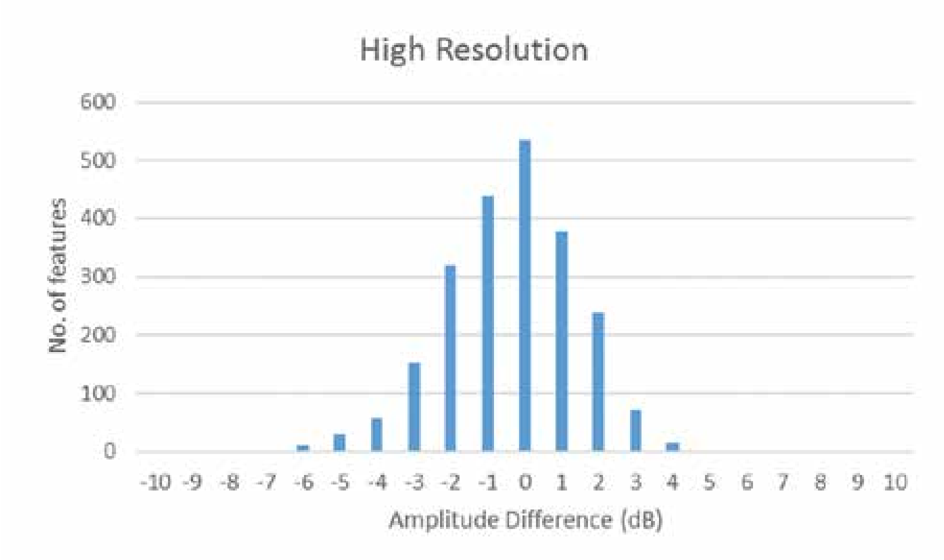

FIGURE 2: High-resolution loop test results, 85 per cent within ±2 dB.

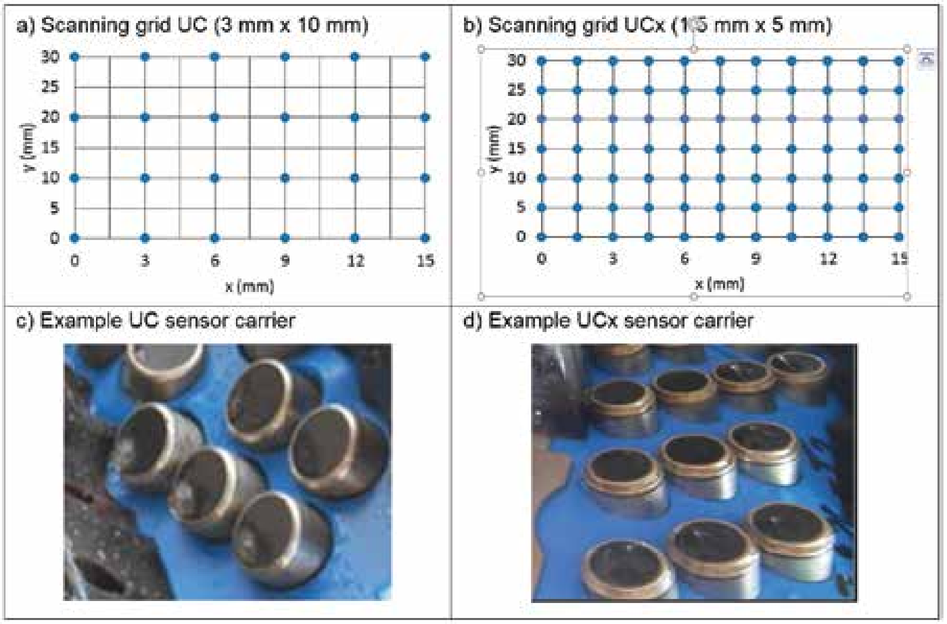

FIGURE 3: Scanning grid for UC and UCx and corresponding examples of sensor carriers.

SCANNING GRID

Figure 3 shows the scanning grid for the standard UC inspection (Figure 3a) and for the latest high-resolution version UCx (Figure 3b). Here, the scanning grid is defined by the axial resolution and the circumferential resolution.

For UCx inspection, the ultrasonic shot density is higher by a factor of four, which increases the data volume by the same factor.

The improvement of the circumferential resolution can also be recognised by the increased sensor density (Figure 3c and 3d).

ENHANCED SIZING

Enhanced sizing (ES) is a new depth sizing methodology for cracks. It is based on additional information extracted from the data recorded by the robot. There are two main benefits to ES:

1. It removes the uncertainty for features >4 mm, meaning the depth sizing in absolute values is for the entire wall thickness range.
2. For the depth range between 1 and 4 mm, ES provides a confirmation of the pulse-echo (PE) depth. ES methodology is ideal for high-resolution inspections up to a maximum wall thickness of 13 mm.

INDIRECT CRACK ECHO

High-resolution is the foundation of the ES methodology, which removes the maximum depth sizing capabilities of 4 mm by conventional PE

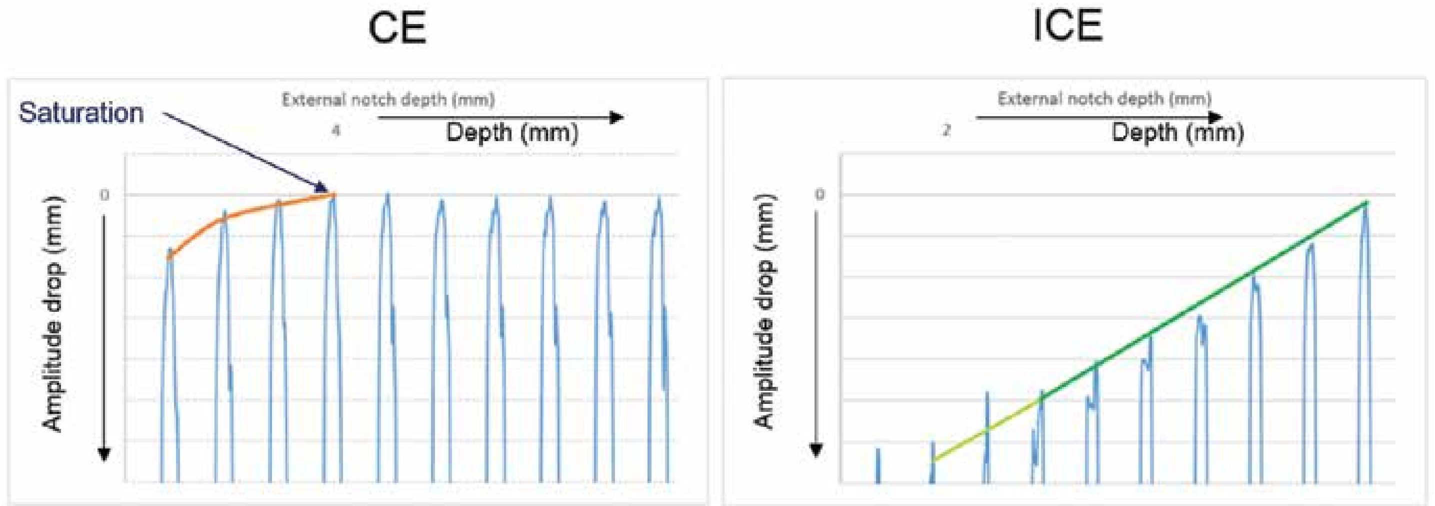

FIGURE 4: CE amplitude response vs increasing feature depth (left) and ICE amplitude response vs increasing feature depth (right).

methods. This methodology also provides a depth confirmation between 2 and 4 mm.

The methodology is based on the indirect crack echo (ICE), which increases proportionally to the depth of the feature. This echo follows a different path than the corner echo (CE) used for PE. ICE is recorded by the robot depending on the position of the sensor relative to the feature. A new depth-sizing algorithm was developed for this methodology, which includes input from conventional PE and the ICE used for ES.

The ICE amplitude is proportional to the depth of the crack. The left side of Figure 4 shows the amplitude from the CE. Once it reaches a depth of 4 mm, the signal is saturated and it is not possible to calculate a depth beyond that point.

The right side of Figure 4 shows the ICE amplitude: the deeper the feature, the higher the amplitude from the signal. ICE continues increasing for the full wall thickness. The sizing algorithm considers this additional information for the depth calculation. The outcome from the algorithm is the reported depth.

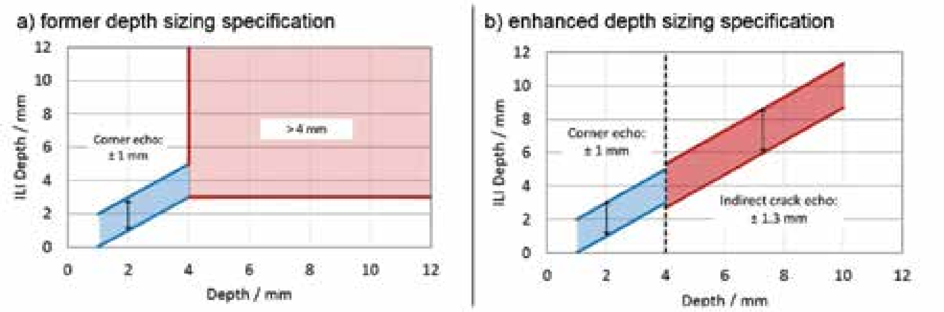

FIGURE 5: Old (a) and new (b) specification range for crack depth sizing.

By exploiting the amplitude of the ICE signal, the range of crack depth sizing can be extended over the full wall thickness where the covered wall thickness range is mainly dependent on the probe diameter. This new approach was verified by modelling studies as well as by comprehensive experimental work including a variety of different pipe diameters and wall thicknesses.

As a result, a tolerance of ±1.3 mm at a certainty of 80 per cent was determined, shown in Figure 5b. Compared to the old sizing specification seen in Figure 5a, where the depth range is limited to the saturation depth of approximately 4 mm, the enhanced sizing approach represents a major step forward regarding the reliability of inline crack inspection. **P**

About NDT Global

NDT Global is a leading supplier of ultrasonic pipeline inspection and data analysis. The company's inspection fleet provides inline inspection services for onshore and offshore pipelines worldwide, with offices located in Australia, Canada, Germany, Ireland, Mexico, Spain, UAE, UK and US.

For more information visit **www.ndt-global.com** and visit NDT Global at Booth 403.