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PREDICTION OF TFM MODE FOR REALISTIC DEFECT IMAGING

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ABSTRACT

Total Focusing Method has emerged in recent years as alternative to standard phased array inspection methods due to its high resolution and the realistic images of defects it provides.

In case of crack-like defects, it provides images where the profile and the tips of the defects are reconstructed using relevant ultrasonic paths, also called reconstruction modes. Such realistic image may allow easy interpretation and stronger diagnostic.

However, correct image reconstruction requires to use relevant ultrasonic paths among many possibilities that can produces artefacts.

In this article, we present a method we developed to predict relevant paths for a realistic TFM image of crack-like defects nearby welds. Validation is achieved on simulated and experimental results. Specimens with realistic defects are inspected with a new acquisition system, Panther, applying real time TFM imaging with selected modes of reconstruction.

Keywords: Ultrasonic testing, TFM imaging, specular echo

NOMENCLATURE

FMC	Full Matrix Capture
TFM	Total Focusing Method

1. INTRODUCTION

Defect characterization is a strategic key in non destructive testing as the type of defect allows predicting its potential evolution. Volumetric defects, such as porosity and inclusions, are generally not dangerous for the material, while planar defects, such as cracks, can spread and create important damages. For both kinds of defects standard conventional and phased array methods provide very close signatures, and it requires an analysis by a specialist operator to discriminate planar from volume defect shapes.

TFM [1,2] produces images directly in the component referential by relocating energy of temporal measured signals at the position of the reflectors which gave them birth. Thereby, in case of planar defects, diffraction echoes are located at the defect tips, and specular echoes along the defect profile, which allows to determine the nature of the defect.

Many possible paths may exist between the transducer and the defects, considering direct path, reflection on the backwall, wave mode conversion. Some specular paths will produce the defect profile, and others will produce artefacts that complicates the image interpretation. We developed a tool, called Specular Echoes Estimator, to determine automatically the relevant reconstruction modes depending on known parameters of the inspection configuration and the wanted defect type.

2. Principle of TFM imaging

TFM imaging is a reconstruction method to optimize focusing at any point of a chosen region of interest (ROI).

It is applied to data collected by Full Matrix Capture (FMC) acquisition. FMC is achieved by successive firing from each element of the array transducer and reception by all elements each time. This process provides a complete set of elementary signals received by all transmitter-receiver combinations of the array transducer. Given N elements on the array transducer, NxN elementary signals will be collected by FMC.

TFM is applied to a selected ROI, defined by a grid. For each point P of the grid, contribution from the elementary signals are defined by the ultrasonic paths between transmitting element, point P and receiving element. The time of flight related to the ultrasonic path determine the amplitude contribution. The full amplitude at point P is the sum of all contribution of all transmitter-receiver.

2.1 Ultrasonic paths

Waves refracted into the inspected specimen can follow various paths according to mode conversion after refraction, reflection of the backwall or the defect, mode conversion after reflection. We consider in this article corner echoes, also called half skip modes, resulting from double reflection on the backwall and the defect. The combination of possible paths and

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longitudinal and transversal waves generate eight reconstruction modes (LLL, LLT, LTL, TLL, LTT, TLT, TTL, TTT).

2.2 TFM multi modes

Multi-modes TFM [3] imaging has been applied on experimental data to illustrate the need to select relevant modes. The inspection configuration in described Figure 1. A 64 elements linear array probe with 5 MHz frequency is used with wedge to detect a 10 mm notch in a 30 mm thick steel plate.

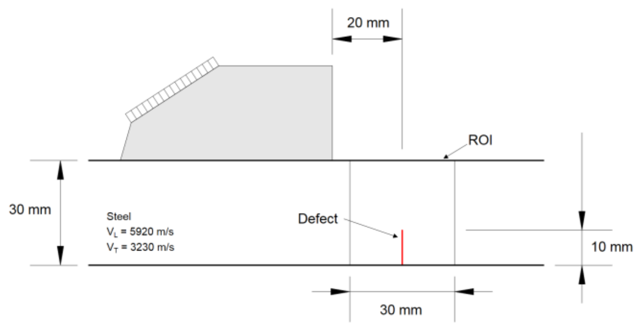

FIGURE 1: INSPECTION CONFIGURATION

Next figure shows 4 (among 8) TFM half skip modes reconstructions of the same ROI. It outlines that only TTT mode can generate a correct drawing of the original notch.

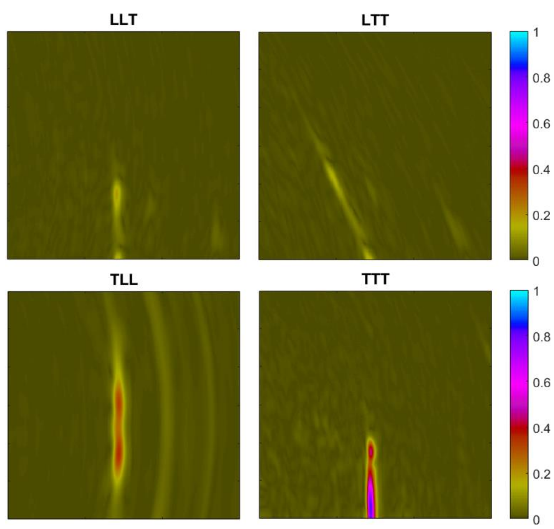

FIGURE 2: TFM WITH HALF SKIP MODES

In this example, TTT mode also produces well located and strong amplitude indications, when all others are weaker and not well positioned (called artefacts).

3. PREDICTION OF RELEVANT MODES

A specific tool has been studied and developed to predict relevant modes for defect imaging and to reduce the number of calculations when it comes to not useful reconstructions.

The specular echo estimator (SEE) was developed to predict the sensitivity of a given mode to a plane defect whose orientation is known regardless of its position and height. It provides a detectability map for which the larger the amplitude, the better the defect detection.

The SEE algorithm is based on the calculation of the elastic field reflected by the planar surface of a defect of known orientation.

The calculation begins by considering that, at each point of the ROI, there is a defect, passing through this point. The specular echo of each point is thus calculated for each transmitter-receiver pair. To model the beam-defect interaction, A specular model has been developed to model the beam-defect interaction. Assuming that the computation point is in the far field, the waves can be approximated by plane waves.

The defect being considered as a perfect reflector, the reflection coefficients are calculated for a solid/empty interface.

We consider that for a specular mode the amplitude of the beam-defect interaction is non zero if Snell law is respected at the running point, considering the planar defect orientation.

From this relation, we construct the SEE mapping for a chosen ROI. The larger the amplitude of the mapping, the better the detection. Null value indicates that no reconstruction of the defect can exist from specular modes.

4. SEE MAPPING EXPLOITATION

Figure 3 shows SEE mapping related to Figure 1, which validates the good reconstruction for TTT mode.

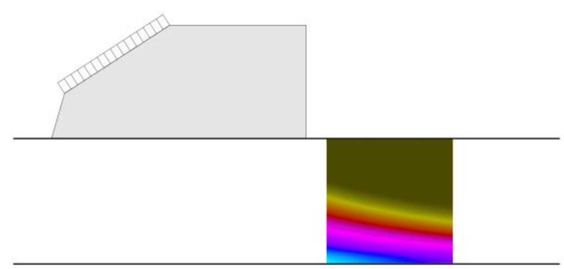

FIGURE 3: TTT SEE MAPPING FOR VERTICAL DEFECT

Computations have been carried out to validate the SEE model and compare simulated and experimental TFM images. Figure 4 presents a configuration experimentally setup on a machined mockup with 14° slope on the backwall and a vertical notch.

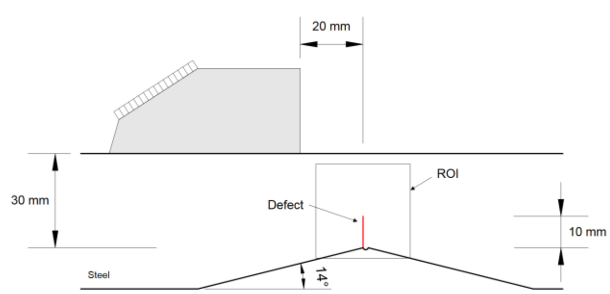

FIGURE 4: INSPECTION CONFIGURATION

Figure 5 presents SEE mapping and TFM image obtained from experimental data. For each mode of reconstruction (TTL, TLT and TTT), TFM images, on the right side, are coherent with the related SEE mapping, on the left side, calculated with the model. TTL and TTT modes produce mainly artefact, when TLT allows drawing the notch at the good location from the back wall.

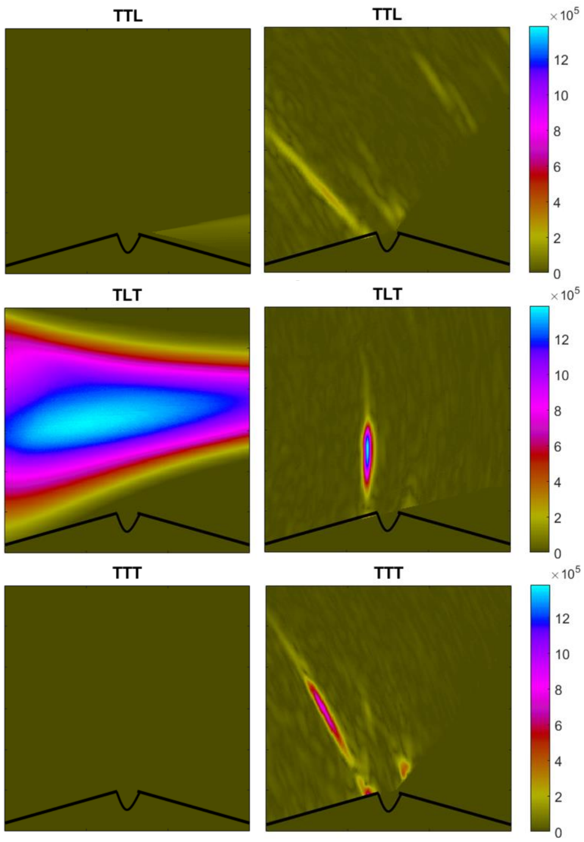

FIGURE 5: SEE MAPPING (left) AND TFM IMAGES (right)

These results validate the ability of the SEE estimator to predict the relevant mode for TFM imaging. It also shows how the backwall geometry affect the reconstruction and may change the relevant modes.

4. CONCLUSION AND PRESENTATION

We have developed and validated a new tool to predict relevant modes for TFM reconstruction of crack like defects. This estimator takes into account the testing configuration and the component geometry as a slope on backwall.

Our presentation at EPRI 2019 will focus on the exploitation of the SEE estimator and TFM imaging applying various modes of reconstruction.

It will be evaluated on specimens with realistic defects to outline its assets and robustness in front of various situation.

A new acquisition system, Panther [4], will be exploited for these experiments. This systems allows real time display of the TFM image with any chosen modes of reconstruction.

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