1.3.44. THE USE OF PSEUDO-DEFECTS IN VALIDATION OF ULTRASONIC STRUCTURAL-HEALTH-MONITORING TECHNOLOGIES

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Introduction. When new ultrasonic techniques for non-destructive testing are introduced, diverse validation tests are required. Signals obtained from samples with well-characterised natural defects (cracks, flaws) or artificial defects (notches, boreholes) are compared with signals measured at undamaged samples, and so the quality of the NDT technique can be assessed concerning reliability and accuracy. That concept finally leads to calibration procedures for ultrasonic systems. Distance / Gain / Size (DGS) – diagrams e.g. give an indication on the size of defects for flaw detectors, and dedicated test blocks are e.g. used to calibrate ultrasonic thicknesses gauges for different kinds of material. The traditional procedures are however only applicable if relatively simple structures are present. If the structural complexity of the investigated samples is increasing, also the efforts for validation tests should increase. This appears usually to be the case for many structural aircraft parts for which applications of structural health monitoring (SHM) systems are discussed.

The basic idea presented here is to replace real defects by non-destructively applied pseudo-defects. To achieve this, the material is subjected to a non-destructive modification. In the present case, this is done by two blocks that are modestly pressed onto both sides of a thin plate (Fig. 1). This material modification leads to specific reflection and transmission characteristics which is similar to certain real defects, if the dimensions of the blocks are adequately chosen. Such as in the case of real defects, the reflection of Lamb waves at artificial pseudo-defects is in principal correlated with local changes of the acoustic impedance.

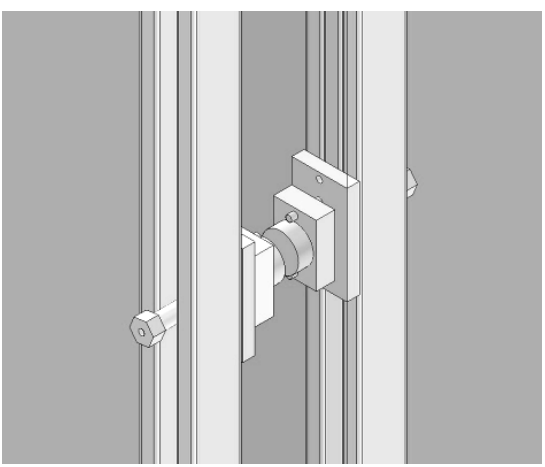

Fig. 1. Facility to apply pseudo-defects (left)

Basic Results and Discussion. The reflection and transmission of Lamb waves is on a theoretical level much more difficult to describe than bulk waves. One of the problems arises from the fact that guided waves can be considered as superposition of numerous elementary waves that irradiate the material interfaces at different angles. This gives reason to all different kind of mode conversions. In the case of Lamb waves, the reflection coefficients are a function of the wave number, k, and the plate thickness, d, and normally, reflections coefficients are in most cases smaller than 1, even in the case of edge reflections. We propose first ideas how the behaviour of pseudo-defects can also be understood on a more theoretical level based on modal decomposition technique.

In order to perform a first proof-of-concept, we used an aluminium plate with a side length of 1 m so that disturbing side wall reflections could be avoided. Piezoceramic patches were adhesively attached to the aluminium plate by cyano-acrylate glue (M-Bond 200). The optimum frequency is in the range of about 400 kHz. The actuators were driven by an arbitrary waveform generator (GAGE – waveform generator) at a frequency of 400 kHz. The output signal consists of Hanning-windowed bursts (5 counts at an output voltage of 10 Vpp). The signals were received by the respective sensors and used without pre-amplification.

The pseudo-defect was attached at different positions and also the orientation of the blocks was varied. The ultrasonic response can be determined for a huge number of positions and geometrical sizes. The detection of the position is possible by the use of the 2D plot (fig. 2) picture.

Summary. The preliminary results clearly indicate that pseudo-defects have the potential to serve as a tool for the validation of defect detection systems in plate-like structures. It affects the same area such as real defects, providing similar variation of reflection and transmission. However the absolute magnitude of the corresponding mode conversion coefficients is different. But it is more interesting to see the trends of how the incremental change of respective dimensional parameters are related to each other (see fig. 2 right). This should finally lead to a library where clear assignments between the ultrasonic signals of real defects and its respective pseudo-defects are possible. The final goal is to establish a mapping for the probability of detection at different positions.

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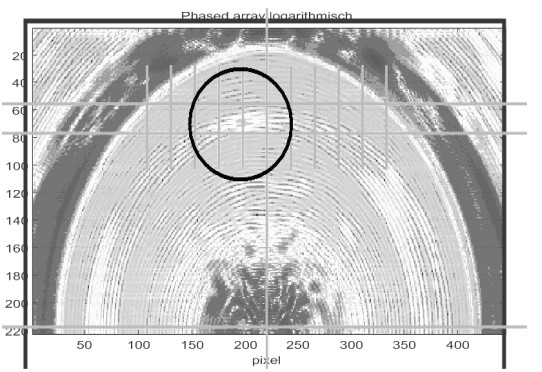

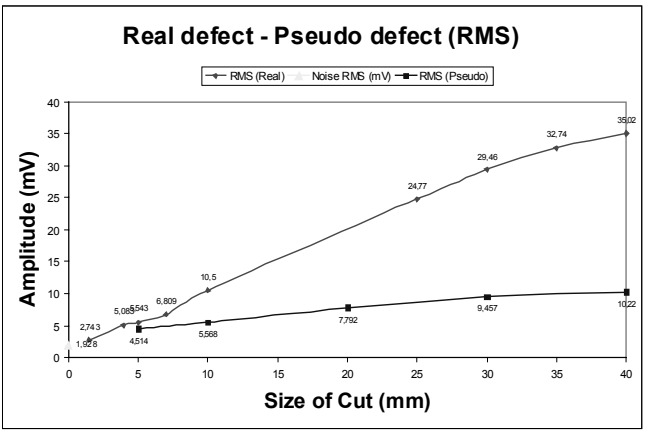

Fig. 2. Pseudo-defect (encircled) apparent in experimental phased-array plot for Lamb waves (left). The most important feature is that the pseudo-defect gave a clear echo that completely disappeared when the pseudo-defect was removed. Increase of reflected amplitude as a function of geometric defect parameters (right)