Ultrasonic array design optimisation for defect characterisation

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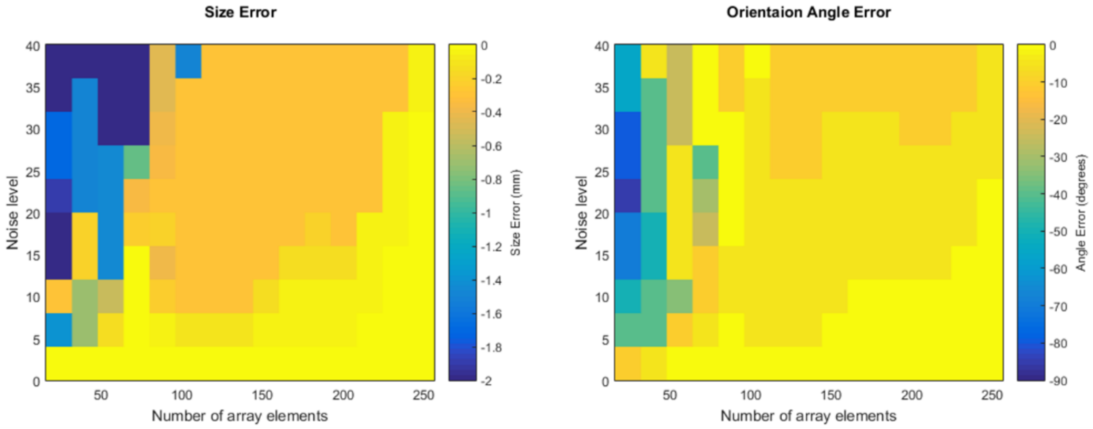
Extended abstract

Ultrasonic arrays are now increasingly used in many industrial inspections. Alongside this development, recent research has provided improved array image quality through Full Matrix Capture (FMC) and the use of a wide range of post-processing algorithms. Arrays have the capability to not only detect and locate defects, but also to provide information about the characteristics of the defect. For a crack, this information is size and orientation angle. But it is also important to be able to distinguish between cracks and other defects, such as volumetric voids and inclusions, which are often much less significant from a structural integrity perspective. An array insonifies a defect from a range of angles and thereby measures part of the matrix of defect scattering matrix. In this way, the scattering matrix encodes the defect characterisation information. Typically, this detail is lost when the FMC data is transformed into an image. However, here we extract this scattering information and use it to characterise small defects. Firstly, we show that under certain conditions, it is possible to determine the defect type, distinguishing between cracks and volumetric defects. Secondly, once the defect type is determined, we show that it is possible to accurately extract parameters such as size, orientation and aspect ratio. We show that this characterisation information is inherently probabilistic and introduce defect probability maps which reveal the most probable defect and the probability landscape. Finally, we show how such knowledge can lead to the design of new arrays, optimised specifically for characterisation. In this step, it is assumed that the defect has been detected and the requirement is now purely to determine its characteristics to the highest possible accuracy. We show that improved characterisation accuracy can be achieved with this optimised approach and suggest that this concept will have benefits for some safety critical applications.

In order to investigate the performance of arrays, we explore the effect of critical parameters, which have a significant impact on characterisation accuracy, such as number of array elements, material noise, array pitch size, defect type and back-wall proximity. To simplify the process, here we only consider crack-like defects whose characteristics are defined as size and orientation angle. We then simulate defects and characterise them using the method explained above and plot the characterisation error against number of array elements and material noise.

Figure 1 illustrates the characterisation error in size and orientation angle, against the number of elements in the phased array and the level of material noise. It shows that as the noise level increases, it takes more elements to accurately characterise a certain defect. This is due to the increase in the angular coverage at which the defect can be insonified and therefore achieving an improved ability of focusing on the defect and reducing the effect of surrounding noise.

Figure 1 can be generated for other circumstances, such as different types of defects, array pitch sizes and back-wall proximities, as well.



(a) (b)

Figure 1. Array performance in characterising (a) size and (b) orientation angle of a simulated crack against number of elements and noise level. The simulated crack has a size of 0.5 mm and is oriented at 60° from the array.