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Simulation of Ultrasonic Testing of Rail Wheel Face using Phased Array and DDF technique

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Abstract

This paper presents a method of increasing the near surface resolution of a rail wheel face inspection. Paper describes the use of Dynamic Depth Focusing (DDF) to detect 1mmFBH @ 6 mm deep in the material while simultaneously detecting defects through the thickness of the wheel face (approximately 138 mm in thickness).

The first part of this paper describes simulation results that are used to obtain the transducer design and optimal array firing size and sequence, followed by discussion of simulation test results.

Introduction

With the growing use of Railway networks creating an increased risk of potential accidents, government regulators have responded by developing new stringent safety standards. The intent of new regulation is to identify and eliminate or mitigate potential risk factors. Resulting in increased inspection and non-destructive testing of various components to mitigate those risk factors. Ultrasonic testing is one such way. This paper describes testing of face section of a rail wheel with increased defect detection using phased array ultrasonic technique.

Dynamic Depth Focusing (DDF)

Unlike the conventional phased array system where one transit shot is fired by a group of elements with a specific delay law and one receive delay law setting is used to receive the signal, the DDF approach is to use a single transmit pulse just like a conventional phased array and then use different and varying receiver delays based on depth.

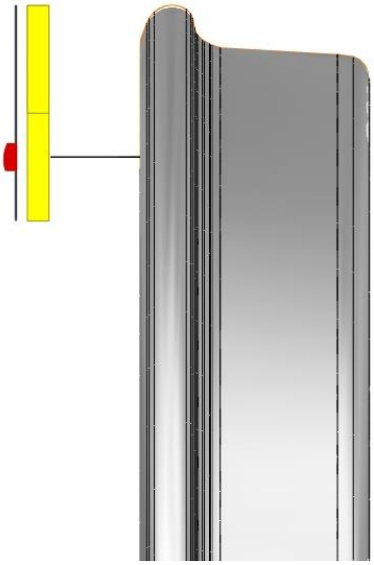
The advantage is much higher signal to noise ratio (SNR) for near surface and better depth of field and sizing of the defects.

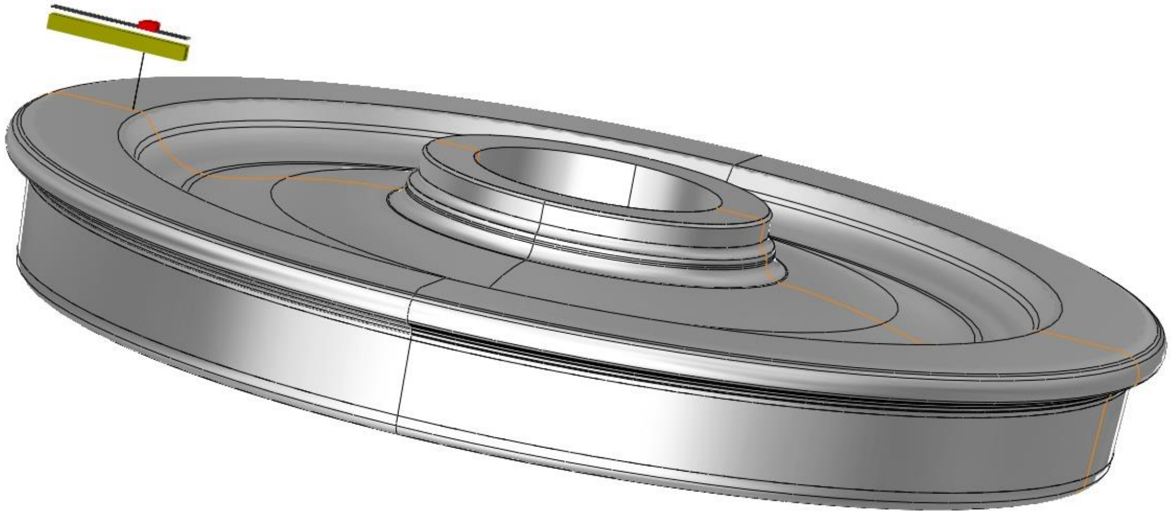
More information about this method can be found in reference https://www.ndt.net/article/v04n09/lamarre/lamarre.htm

CIVA Simulation

Simulation is performed to optimize the transducer size, number of elements to group together and width of the linear array.

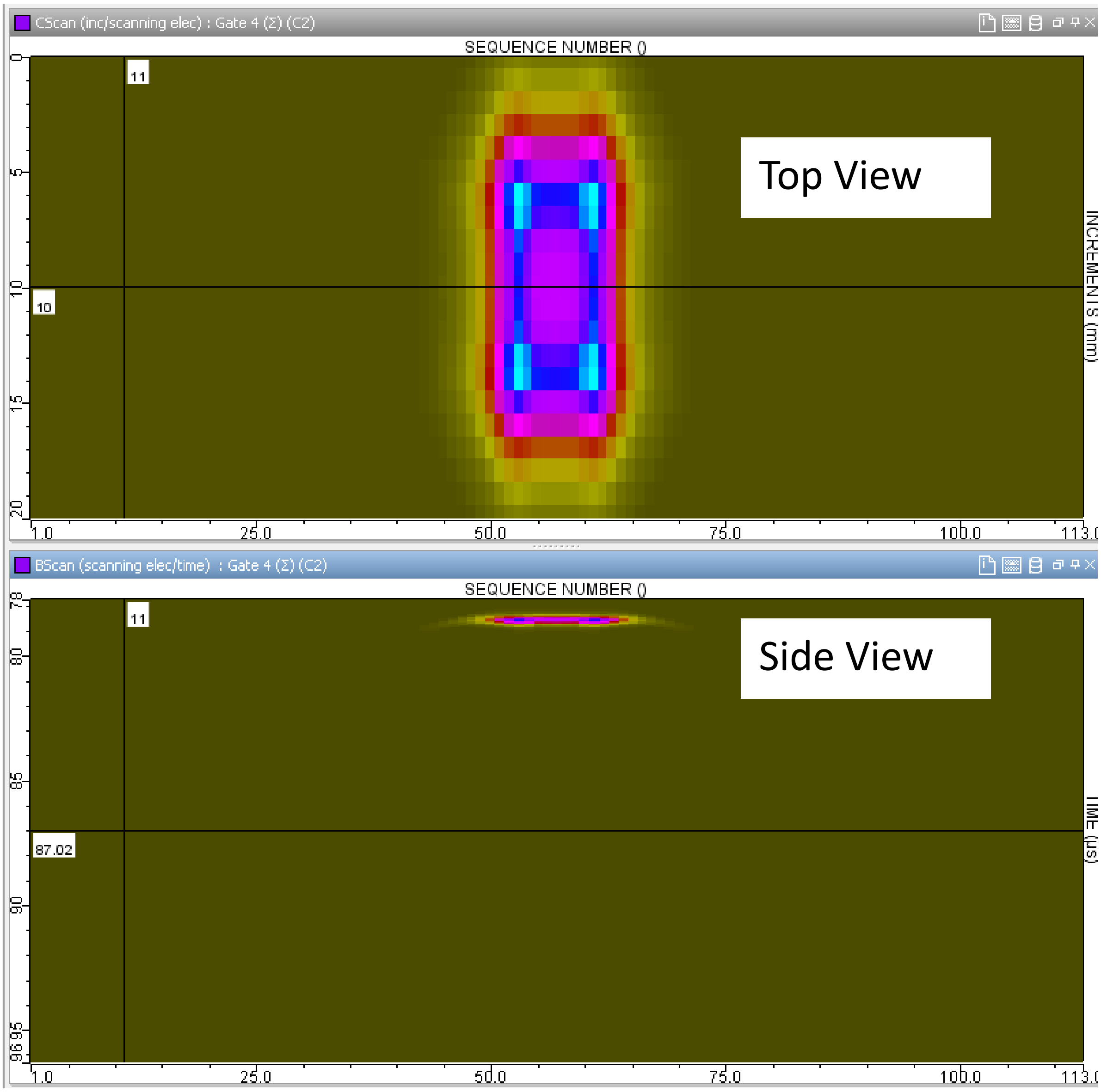
A 5 MHz linear array is used to scan the face of the wheel. 1mm FBH is used as a standard defect located at various depths ranging from 5 mm to 170 mm from the top surface. Pictures below show the area under inspection on a Rail wheel.





Following are the results showing sounds in top and side view with and without using DDF at different depth for a 1mm FBH.

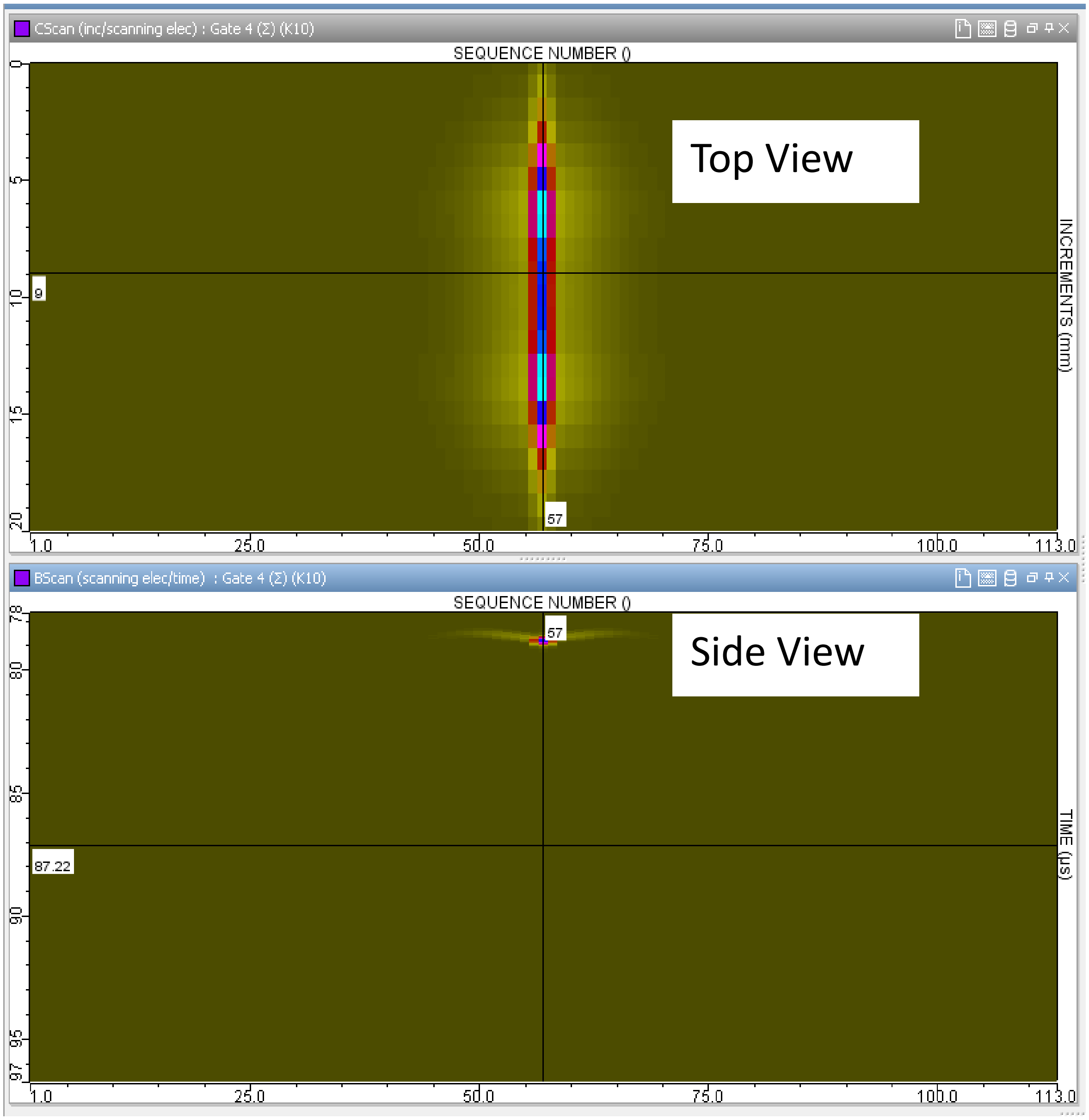
5mm Depth without DDF



Top view shows the beam width as seen from top of the probe and the coverage provided.

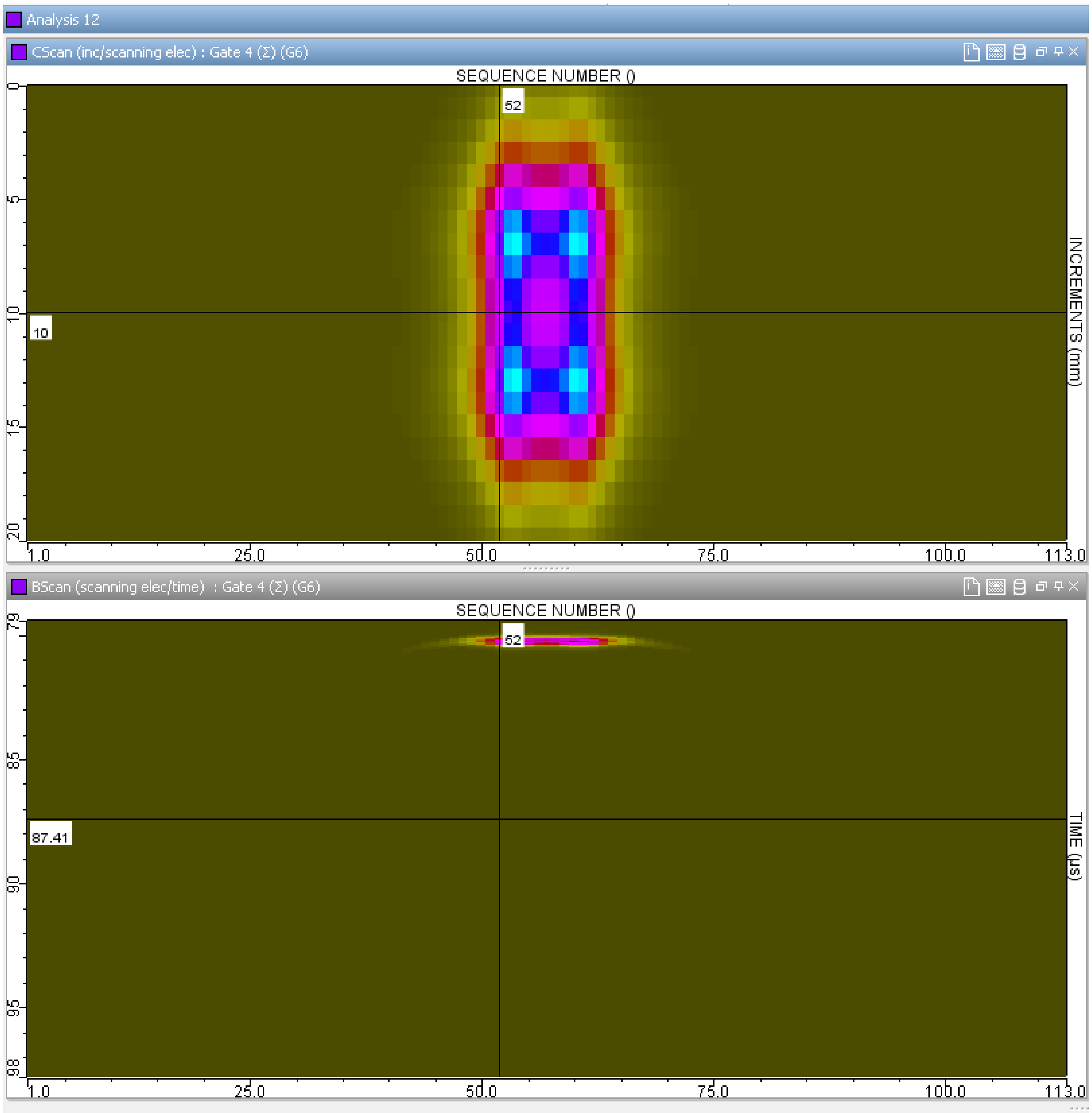
Side view shows a B-scan view of the same defect.

5mm Depth with DDF



As compared to the scan without DDF the beam with DDF is much more focused and hence the defect sizing and detection in much better. There is a significant difference in the amplitude level as well (Cannot be interpreted from these images). This difference in amplitude helps to detect the defect in presence of an interface echo.

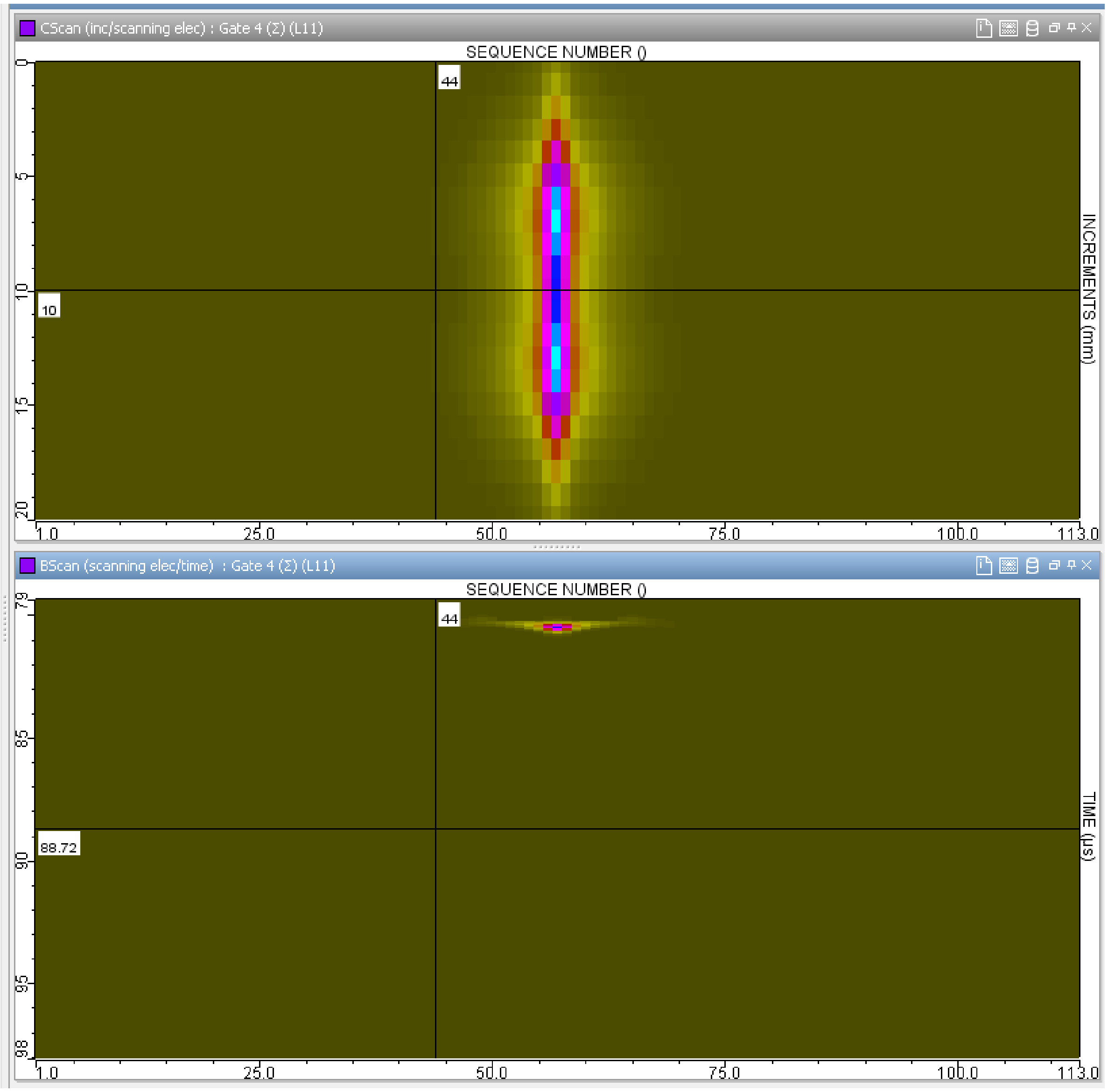
10 mm Depth without DDF



Similar results are seen for 1mm FBH at a depth of 10 mm from the surface. Using DDF enables higher amplitude detection and correct sizing.

Number of DDF points required to get type of resolution throughout the thickness of material under test will be a function of type and size of the defect and the thickness of wheel face.

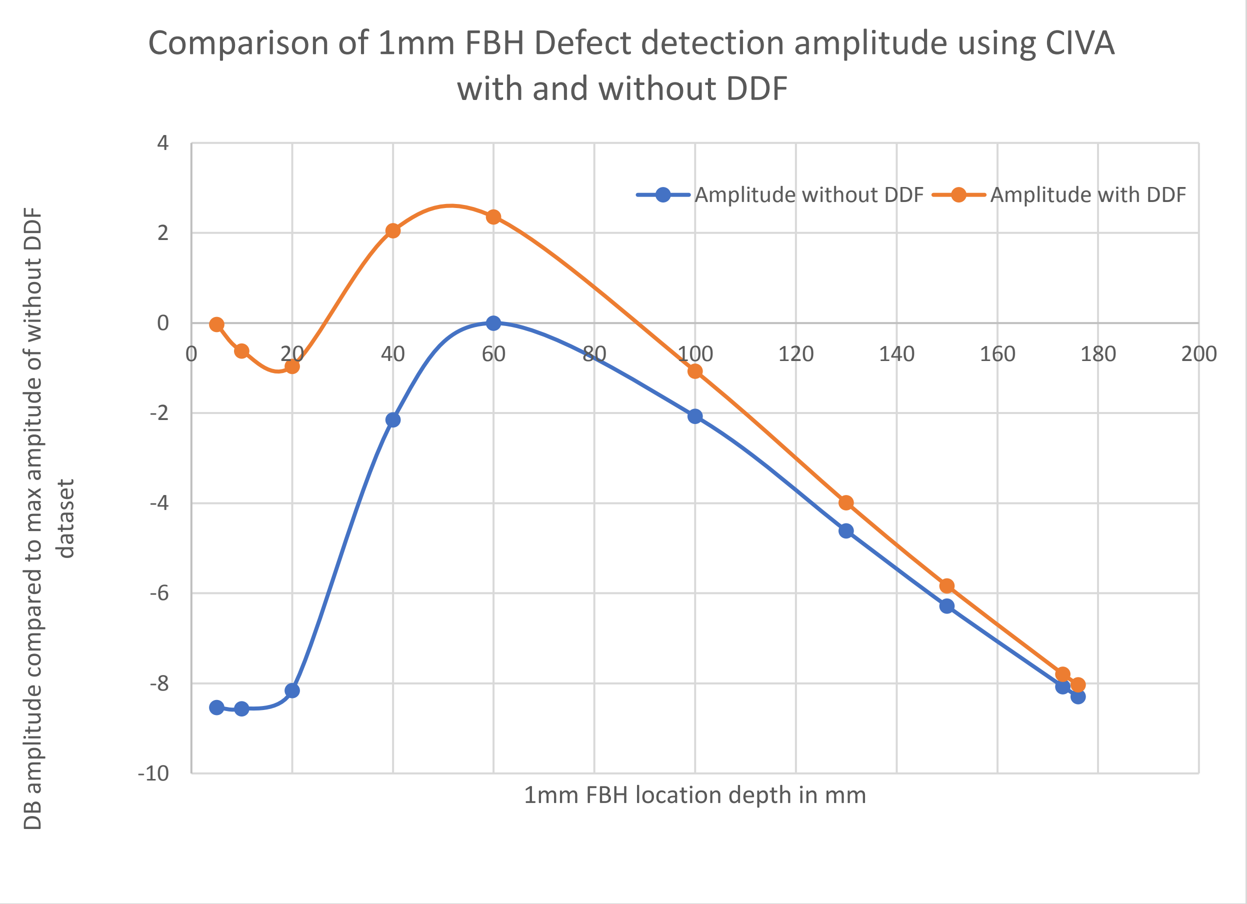
10 mm Depth with DDF



The chart below provides a comparison of the increase of amplitude using DDF in dB scale while using amplitude without DDF at 60 mm depth as reference amplitude. X-axis is the depth of 1mm FBH from the surface of the wheel face in mm.

The chart shows an increase in amplitude of 5 mm deep, 1mm FBH of approximately 8 dB compare to amplitude without using DDF. Similar increase is seen at 10mm depth. This is significant as this is within the ringdown region of the probe and increasing the amplitude in this region would possible be the difference between detection and non-detection.

As the depth of the 1mm FBH increases, the difference between amplitude with and without DDF decreases and the effect of DDF is reduced.



Conclusions

The results of simulation indicate that optimized transducer design can be used to detect 1mm FBH 5mm from the surface using DDF while simultaneously detecting defects at 140 mm.

DDF as expected is very effective in increasing the amplitude of defects in the near surface region increasing the depth of field and defect resolution. Next steps are to run experimental trails using the probe and confirm the results.