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A Study of Rail Wheel Face Using Phased Array and Dynamic Depth Focusing (DDF)

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Abstract

This paper is the continuation of the work reported in earlier white papers titled “Simulation of Rail Wheel Face Ultrasonic Testing using Phased Array Probe and DDF technique” and “Near Surface Resolution improvements in Rail Wheel Face Ultrasonic Testing using Phased Array”.

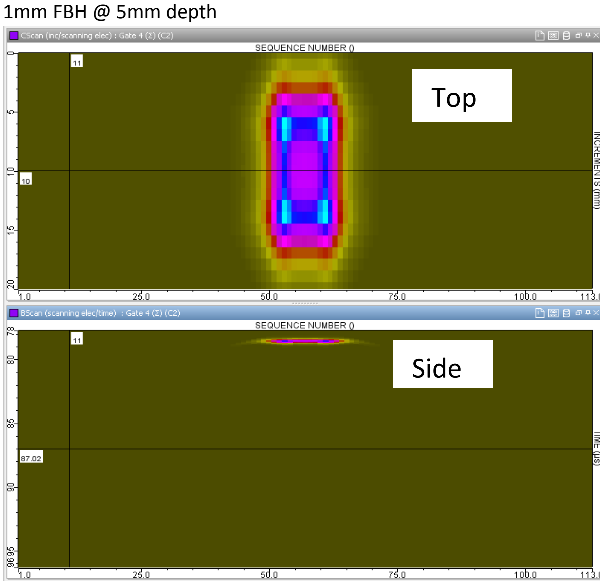
First paper described CIVA simulation results of using Dynamic Depth Focusing (DDF) to detect 1mmFBH @ 5 mm deep in the material while simultaneously detecting defect through the thickness of the wheel face (approximately 138 mm in thickness).

In the second paper the data showed there is marked improvement in near surface detection capabilities both in detection and in sizing to defects using DDF. 5 mm deep defect is not recordable or visible to inspection using standard approach. With DDF, the defect can be detected and recorded without comprising on the through of the system. This paper will present results of experimental study through the full depth of the wheel face using DDF and compare it to the simulation results.

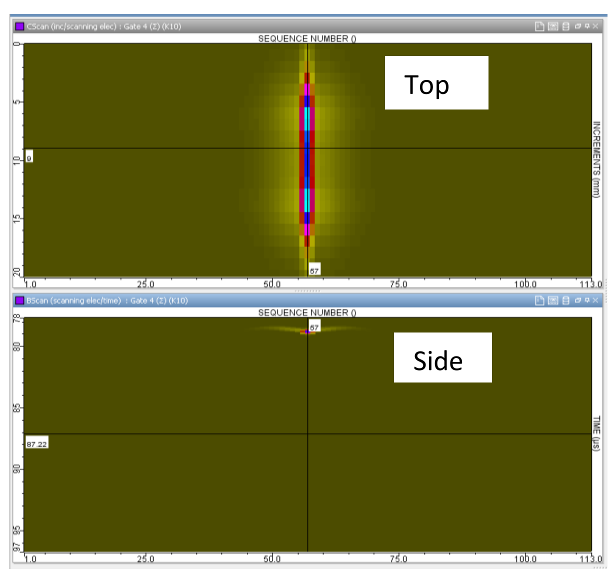
Simulation

The details of the simulation setup are presented in the first white paper. Presented here are the sound field maps for different depths for a 1mm FBH defect response signal.

1mm FBH @ 5mm depth



Without DDF



With DDF

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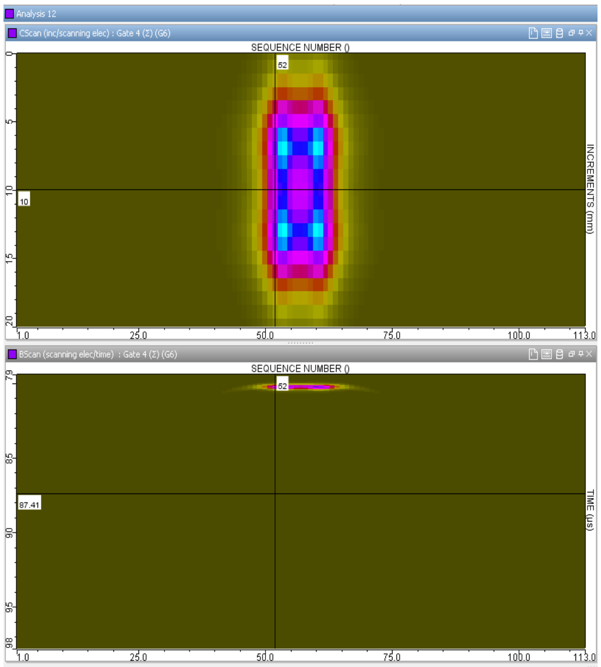
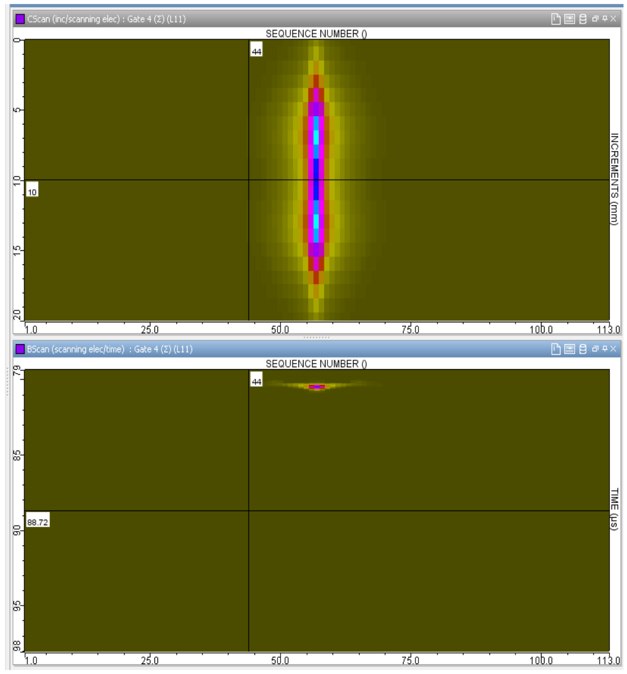
1mm FBH @ 10mm depth

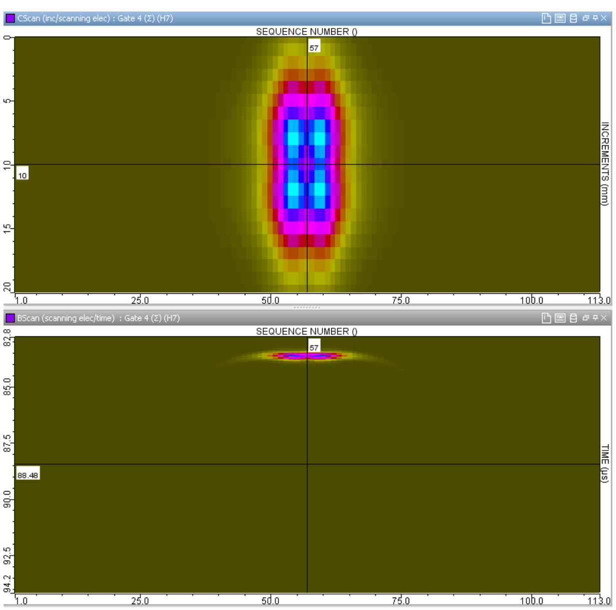


Without DDF

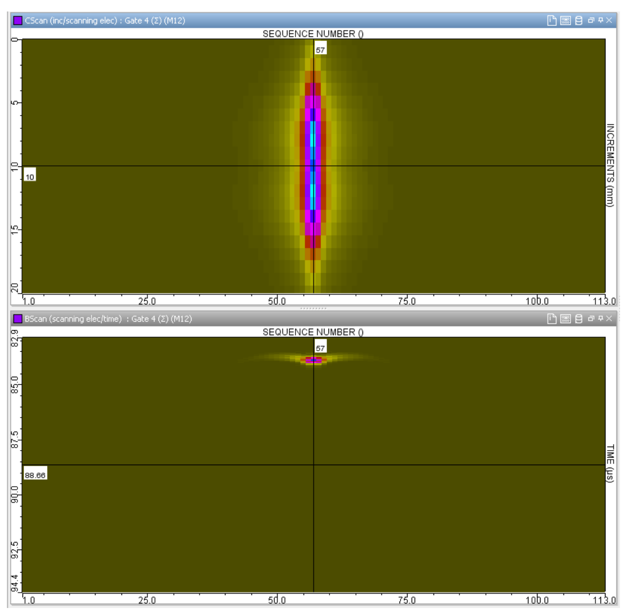


With DDF

1mm FBH @ 20mm depth

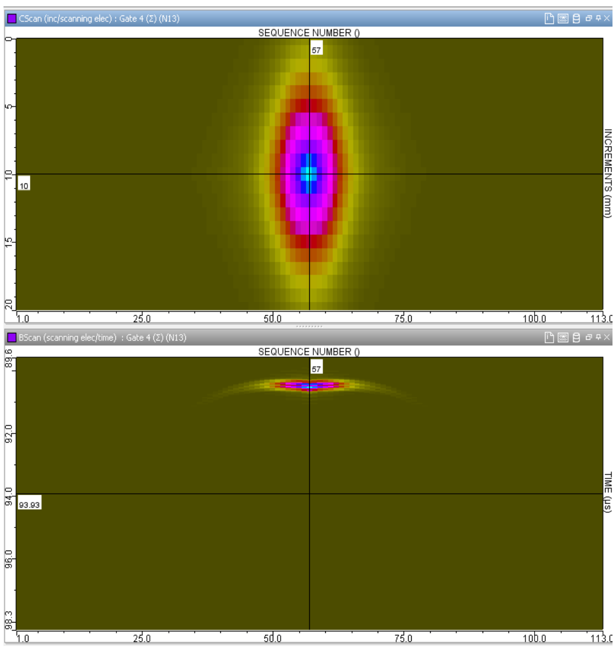


Without DDF

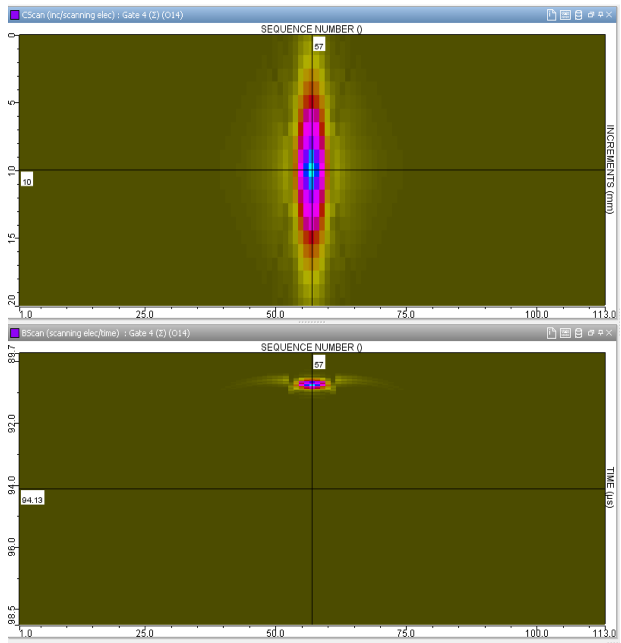


With DDF

1mm FBH @ 40mm depth

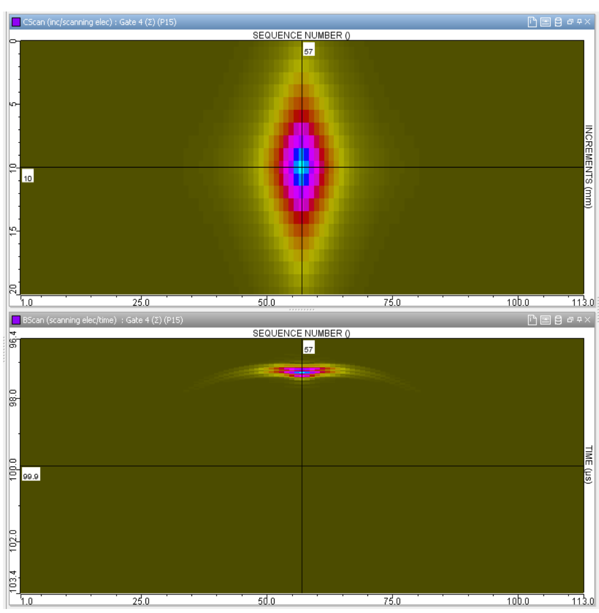


Without DDF

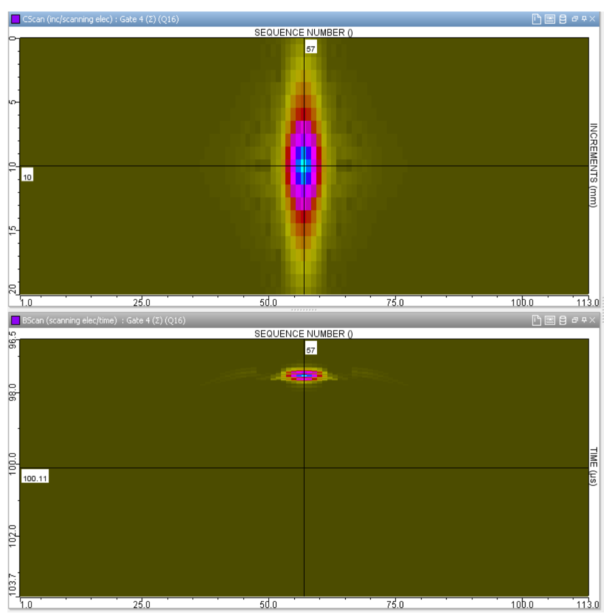


With DDF

1mm FBH @ 60mm depth



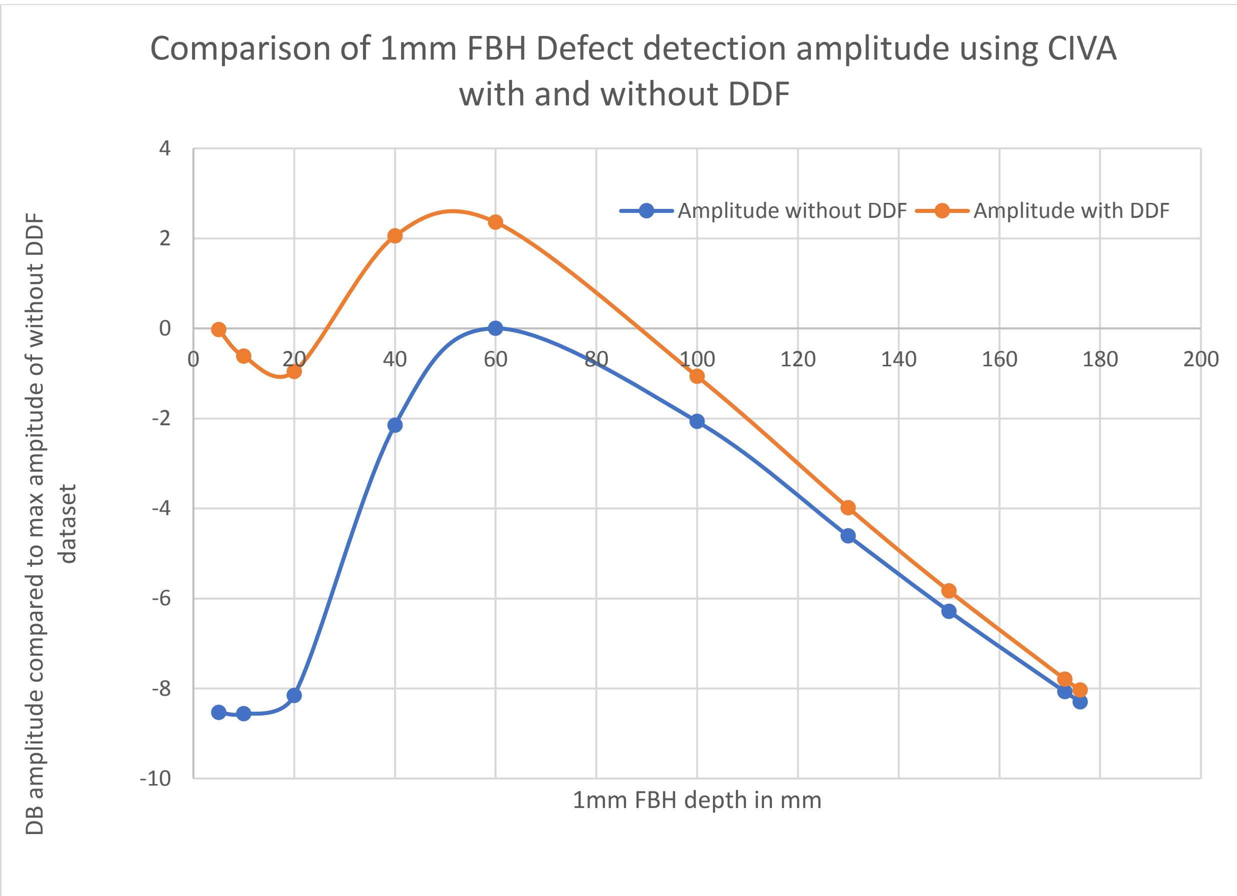
Without DDF



With DDF

For a 1mm FBH at depths ranging from 5 to 60 mm the defect response signal shows remarkable improvement in depth of field and resolution of defect size. The response without DDF have diverging response which either are too low in amplitude for detection or to diverged to size the defect correctly. DDF improves the response on both counts.

The chart below shows two curves, Orange curve represents in the amplitude in dB for 1 mm FBH at different depth using DDF. The blue curve represents the same without DDF. The dB calculation is based in the maximum amplitude at 60 mm depth without using DDF.



Experimental Setup and Results

The results of the simulation suggested that using an optimized probe in congestion with DDF will increase the near surface detection and sizing capabilities of the probe through the thickness of the Rail wheel face.

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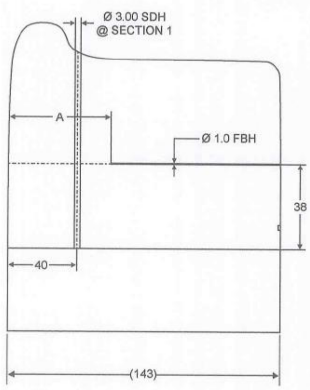
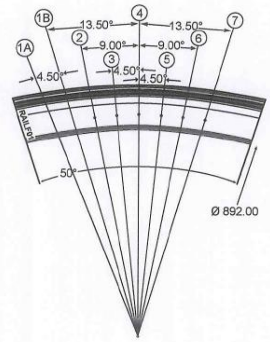
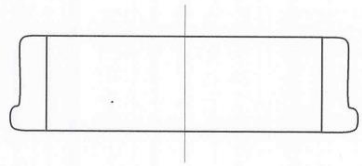
To experimentally verify these results a wheel sample is cut and 1mm FBH defects with known depths are machined at various radial locations as shown in the picture below.



DEFECT SECTION A	DEPTH (MM)	HOLE DIAMETER (MM)	METAL PATH (MM)	TYPE
1A	FULL PATH	3.075	40.00	SDH
*1B VOID	VOID	VOID	VOID	SDH
2	137.83	1.008	5.17	FBH
3	133.09	1.010	9.93	FBH
4	113.07	1.005	29.93	FBH
5	83.19	1.013	59.81	FBH
6	42.91	1.012	100.09	FBH
7	5.13	1.011	137.87	FBH

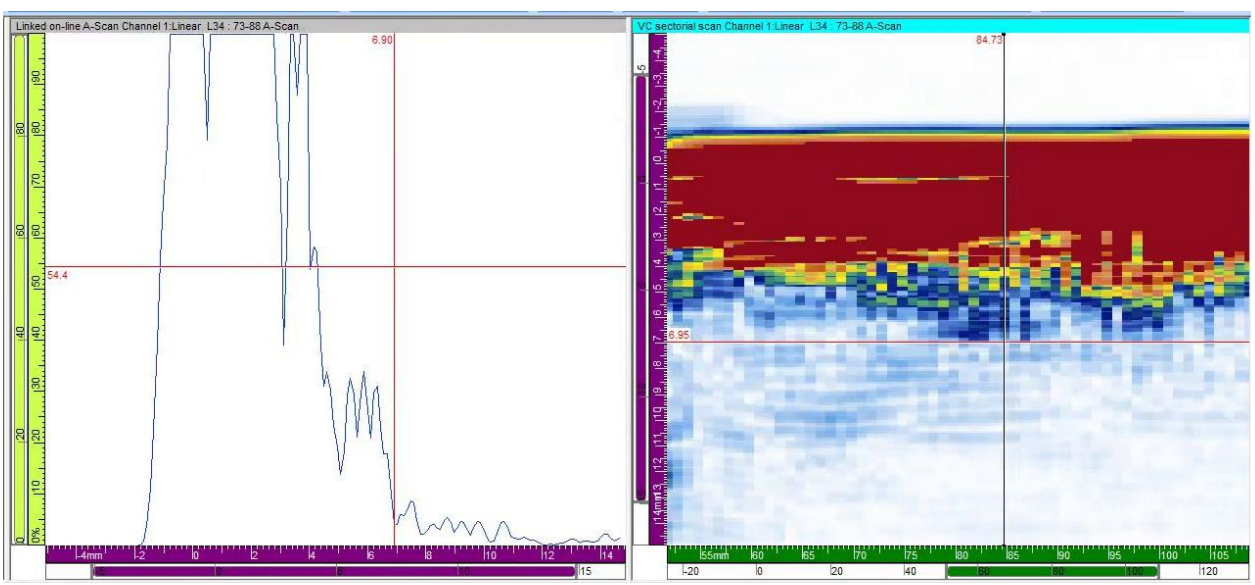
NOTE: ALL MEASUREMENTS ARE IN MILLIMETERS.
HOLES 2-5 ARE COUNTERBORED AT 3.3mm Ø
*SDH 1B IS VOID DUE TO DRILL REMAINING INSIDE OF HOLE.





In the pictures below the 1mm FBH located at 5 mm deep without any DDF is shown in the B-scan as well as A-scan view as seen in the experiment. The main point to be noted is the defect is completely obscured by the interface echo and Low amplitude of reflection.

5 mm deep 1mm FBH with no DDF Experimental result



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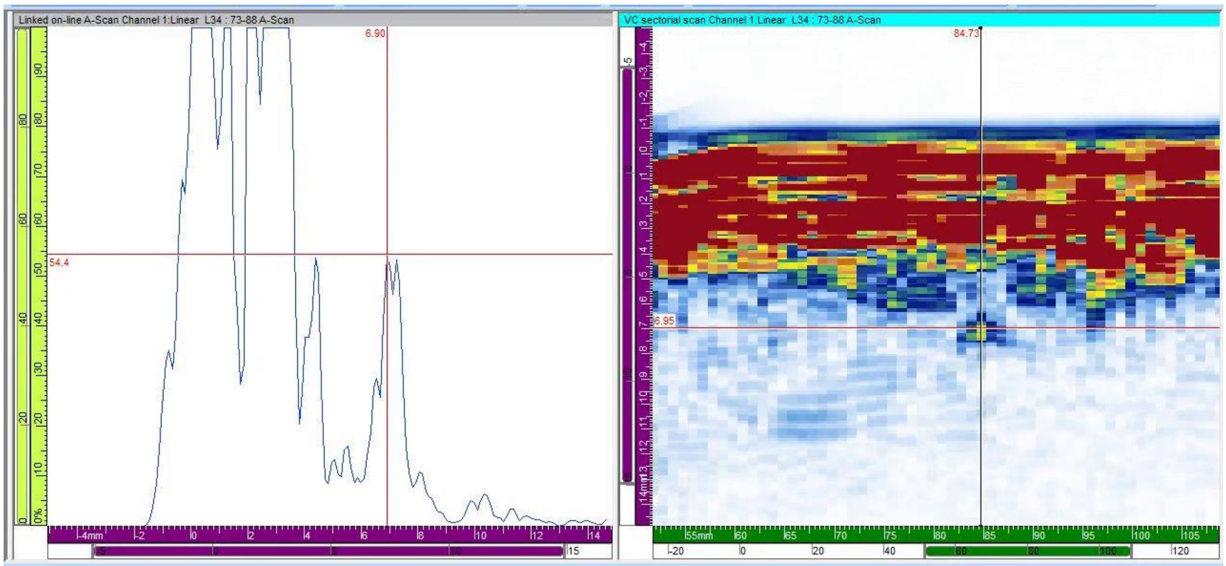
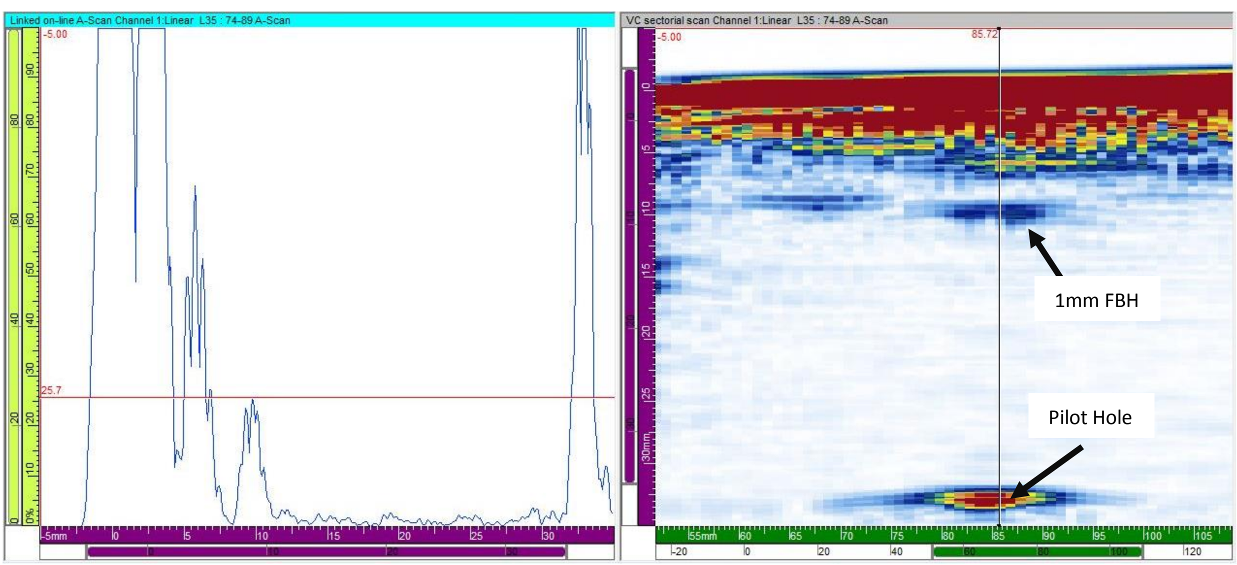
Next set of pictures shows the results of 1mm FBH at a depth of 5mm using DDF. The defect can be seen clearly and has good separation from the interface echo. There is marked improvement in the signal strength as can be seen in the A-Scan. Increasing both the amplitude and sizing resolution.

5 mm deep 1mm FBH with DDF Experimental result

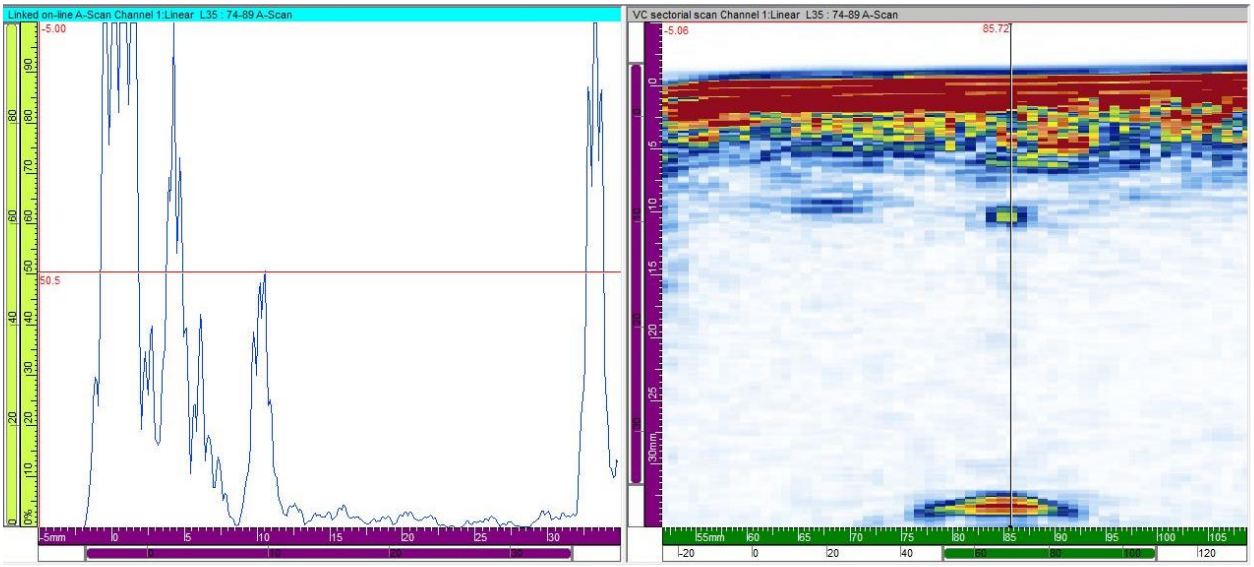


This pattern of increasing amplitude and sizing resolution is seen in the data below for all the different depths reported in the pictures below.

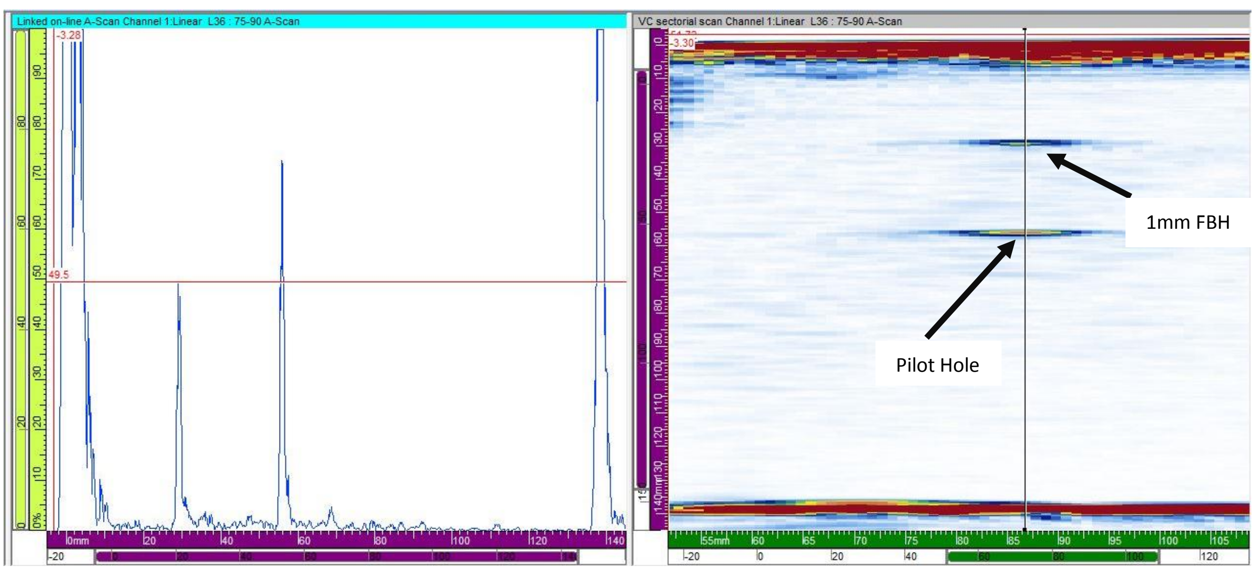
10 mm deep 1mm FBH with no DDF Experimental result



10 mm deep 1mm FBH with DDF Experimental result



30 mm deep 1mm FBH with no DDF Experimental result



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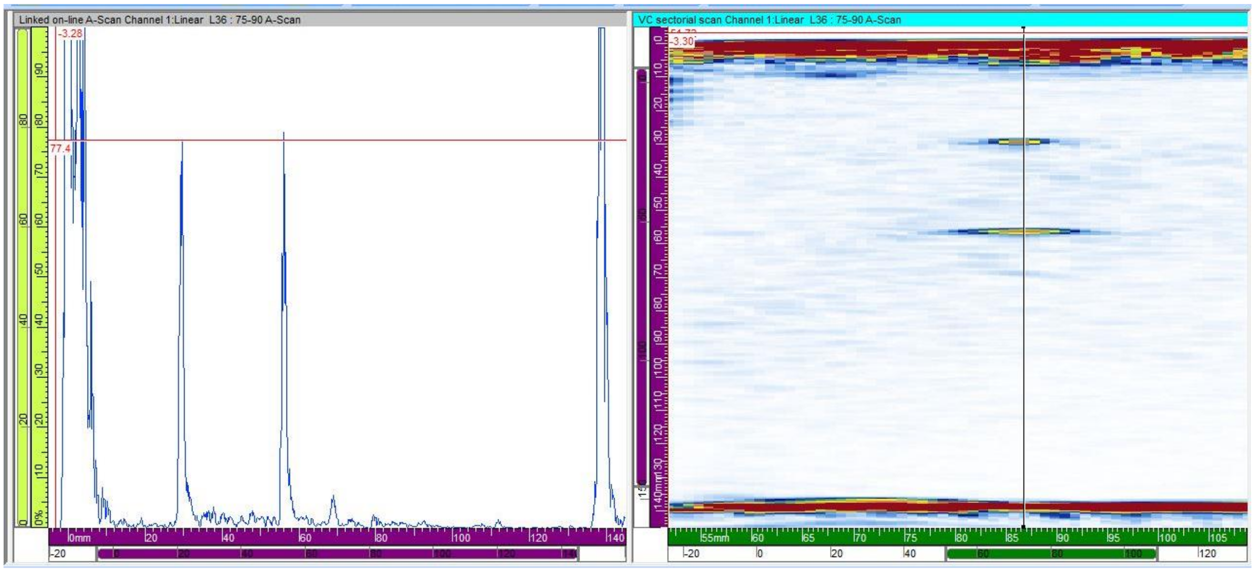
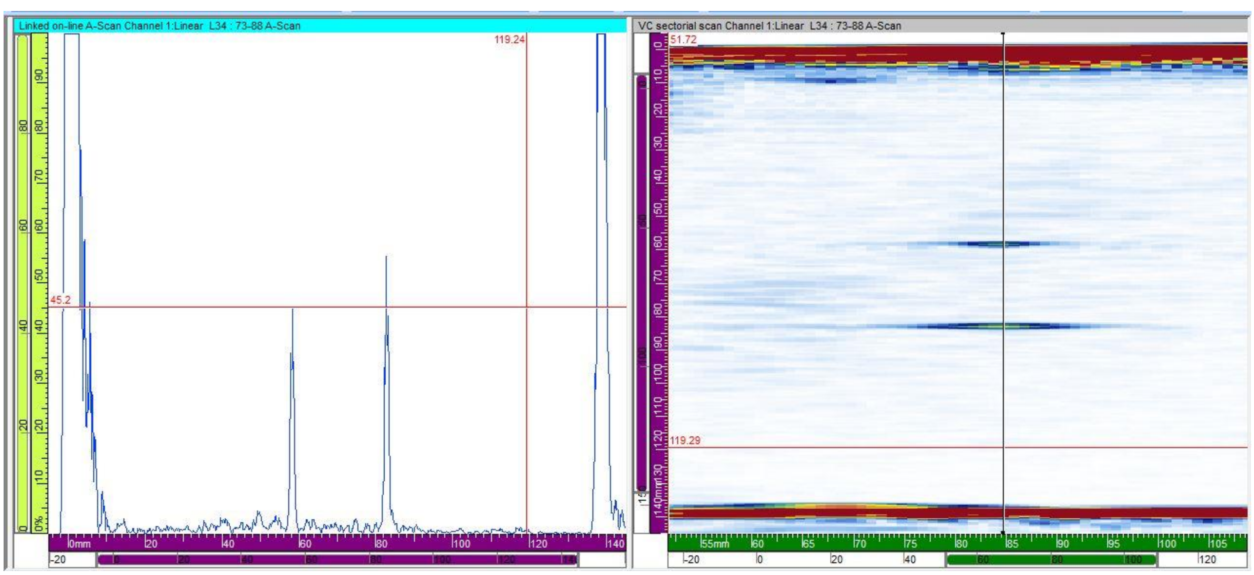
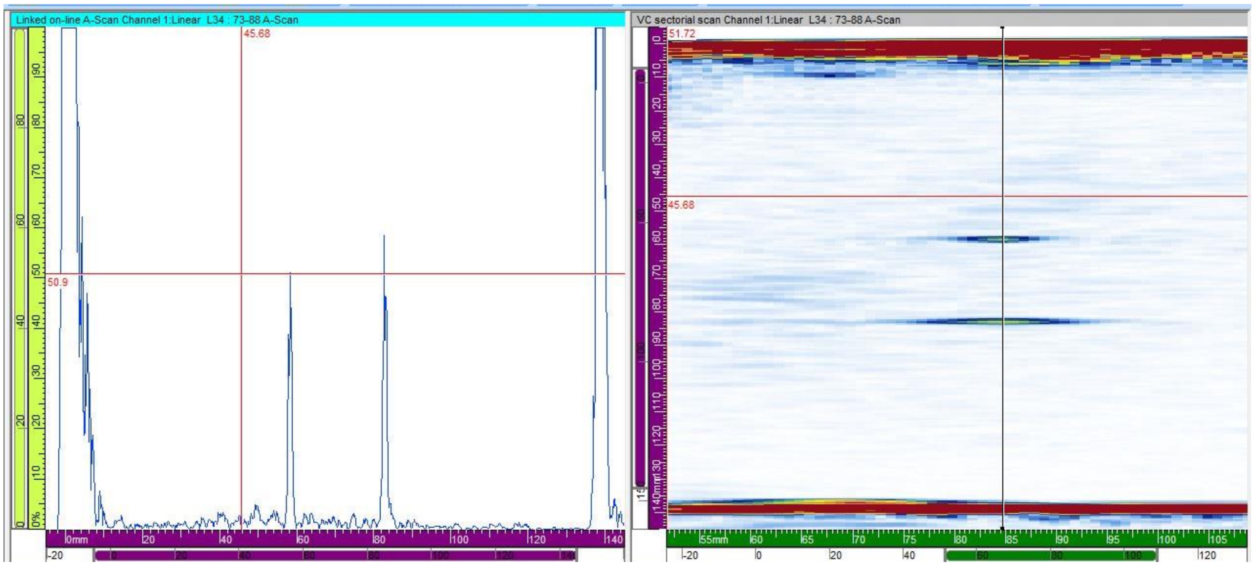
30 mm deep 1mm FBH with DDF Experimental result



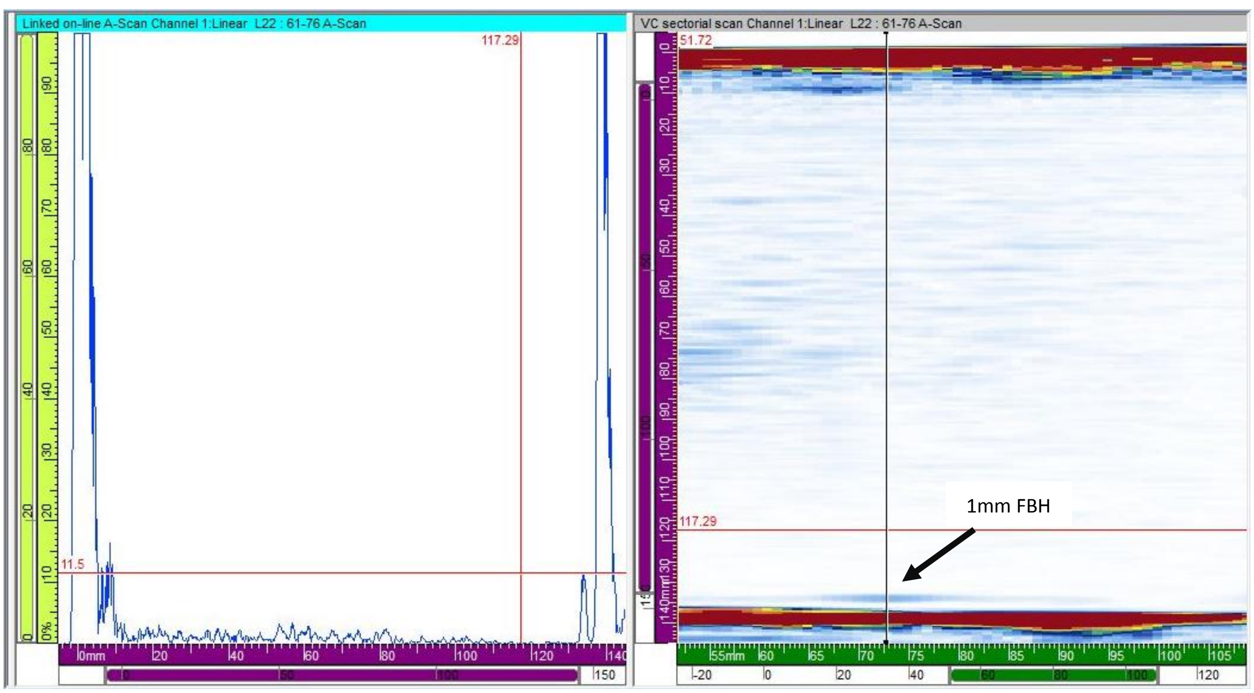
60 mm deep 1mm FBH with no DDF Experimental result



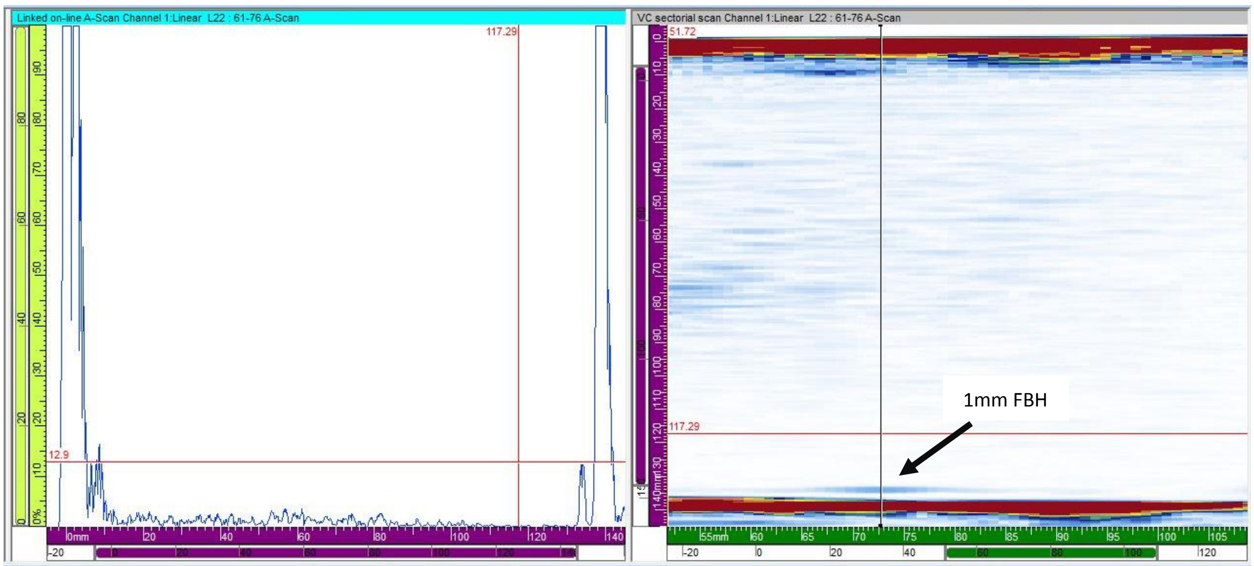
60 mm deep 1mm FBH with DDF Experimental result



137 mm deep 1mm FBH without DDF Experimental result



137 mm deep 1mm FBH with DDF Experimental result



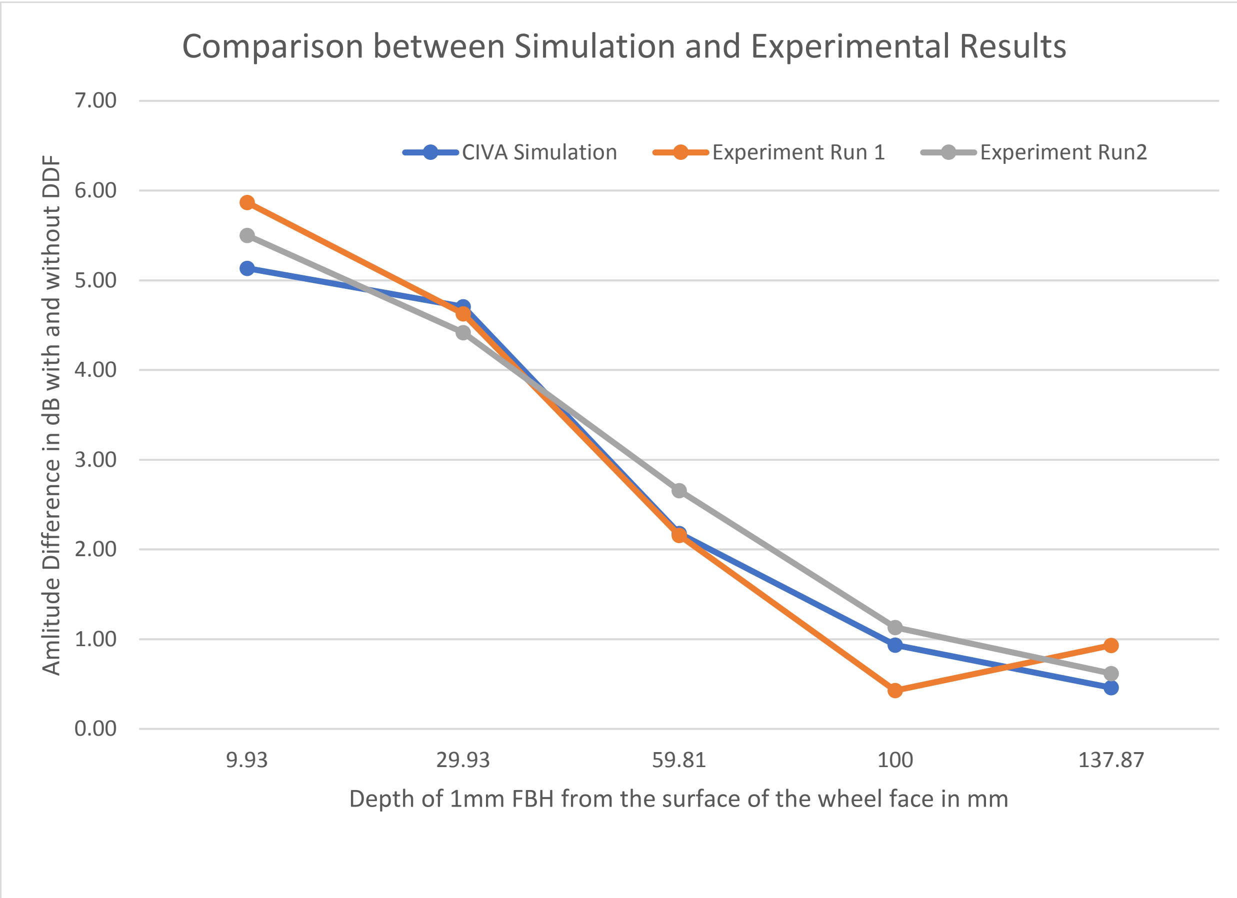
For every depth in the experimental setup the maximum amplitude of defect response in recorded with and without DDF. Two independent experimental runs are performed for measurement of amplitude to consider the effect of experimental fixture's variation.

Same max amplitude data set is extracted from simulation and plotted on a graph.

The graph below represents the dB difference in amplitude for a 1mm FBH with and without DDF as predicted by the simulation and with two experimental runs.

Comparing the experimental runs with simulation results over depth range of 10 mm to 137 mm shows good agreement with the maximum difference of 0.7 dB between the experiment run 1 and simulation at the depth of 10 mm. This difference is attributed to the experimental fixture as can be observed in the second experimental run.

The plot does not include a data point for 5mm depth as it was not possible to detect and record amplitude of 1 mm FBH at that depth without DDF.



Conclusion

The rail wheel face probe experimental data for a 1mm FBH at depth range from 5 mm to 137 mm is recorded with and without use of DDF. Simulations are performed with the same settings. The results indicate good agreement between experiment and simulation.

Using DDF improves the near surface capability for detection of defects as close a 5 mm from the interface echo (i.e. Rail Face). Also, enabling one to exceed the detection criteria presented in EN13262 and ISO 5948 for Rail Face (Rim Axial) inspection.