MAGNETIC ANALYSIS CORPORATION
103 Fairview Park Drive, Elmsford, New York, 10523-1544
Tel: 800-4NDT MAC ~ 914-530-2000~ Fax: 914-703-3790
Internet: www.mac-ndt.com ~ e-mail: info@mac-ndt.com

Near Surface Resolution improvements in Rail Wheel Face Ultrasonic Testing using Phased Array

Anand Desai, Ph.D.

Abstract

This paper is the continuation of the work reported in an earlier white paper titled "Simulation of Rail Wheel Face Ultrasonic Testing using Phased Array Probe and DDF technique".

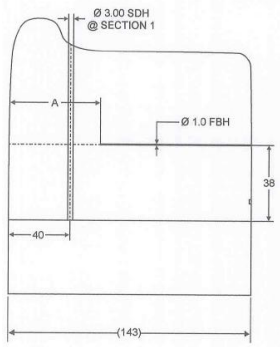
The previous paper described CIVA simulation results of using Dynamic Depth Focusing (DDF) to detect 1mmFBH @ 5 mm deep in the material while simultaneously detecting defects through the thickness of the wheel face (approximately 138 mm in thickness).

This paper continues the work by comparing the results of simulation with experimental results in the near surface region.

Experimental Setup and Results

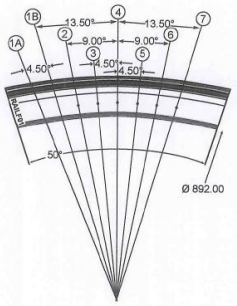
The results of the simulation suggested that using an optimized probe in combination with DDF will increase the near surface detection and sizing capabilities of the probe through the thickness of the Rail wheel face.

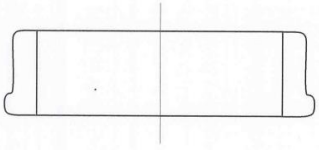
To experimentally verify these results, a wheel sample is cut and 1mm FBH defects with known depths are machined at various radial locations as shown in the picture below.



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.



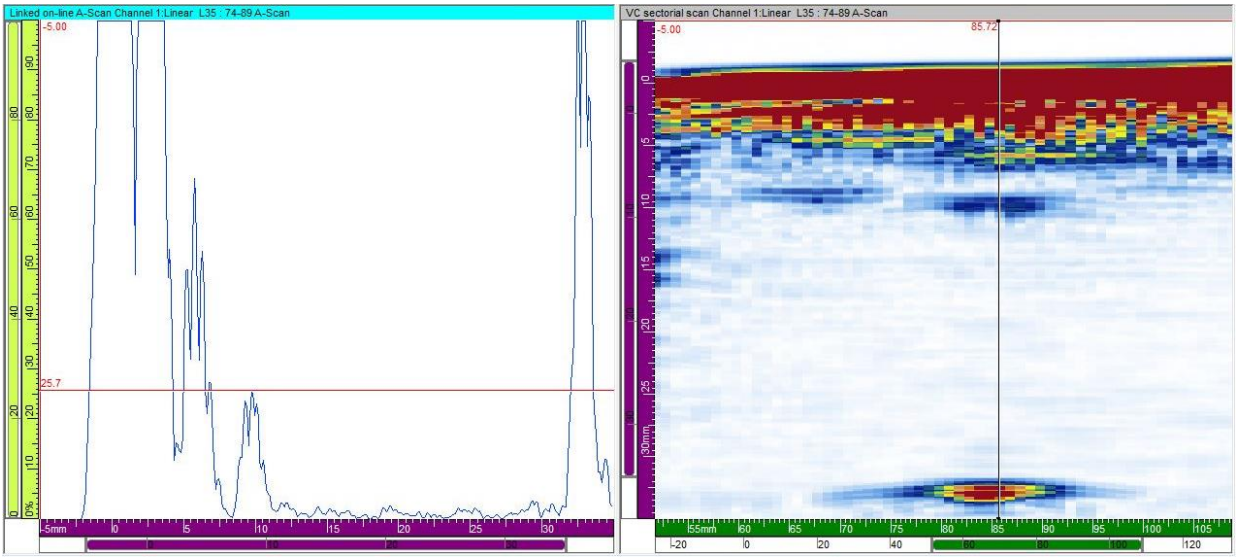


A 5 MHz linear array is used to scan the face of the wheel. 1mm FBH is used as a standard defect located at various depths ranging from 5 mm to 137 mm from the top surface. The phased array transducer used has 128 elements and a group of 16 is combined to form a virtual probe. The optimized design from the simulation is used to procure an identical probe. The experiment is conducted in immersion and the water path is set to replicate as closely the simulation settings.

In this paper the near surface detection (up to 10 mm) capability with and without DDF is studied for rail wheel. The simulations produce a result but in real life the detection of near surface defects depends on the interface echo. The amplitude and ringdown of the probe can either mask the defect or make the defect unresolvable from the background. These experiments will show the true capability of detection of this probe and settings combination.

In the first set of pictures below the 1mm FBH located at 10 mm deep is shown in the picture in the B-scan as well as A-scan view as seen in the experiment and the next picture is the visualization of the simulation result of the same.

10 mm deep 1mm FBH with no DDF Experimental result



Comparing the two results shows the beam seems to have spread as predicted by the simulation. In the experimental A-scan the amplitude of the return signal can be seen for the 1mm FBH. The resolution of the defect from the background is possible but the sizing will not be very accurate.

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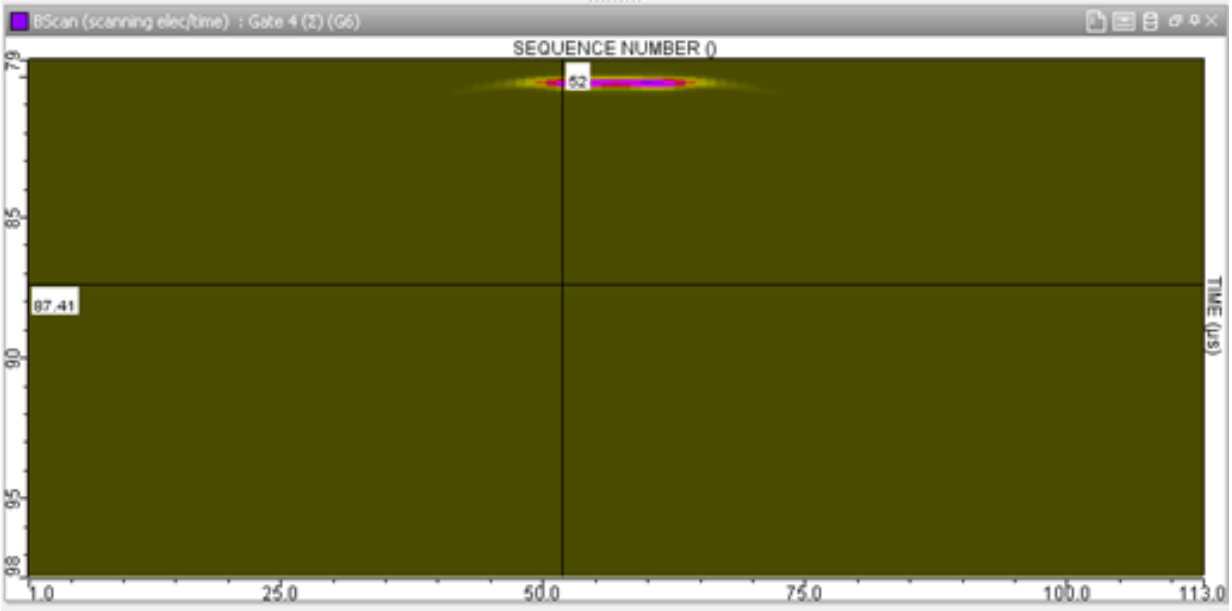
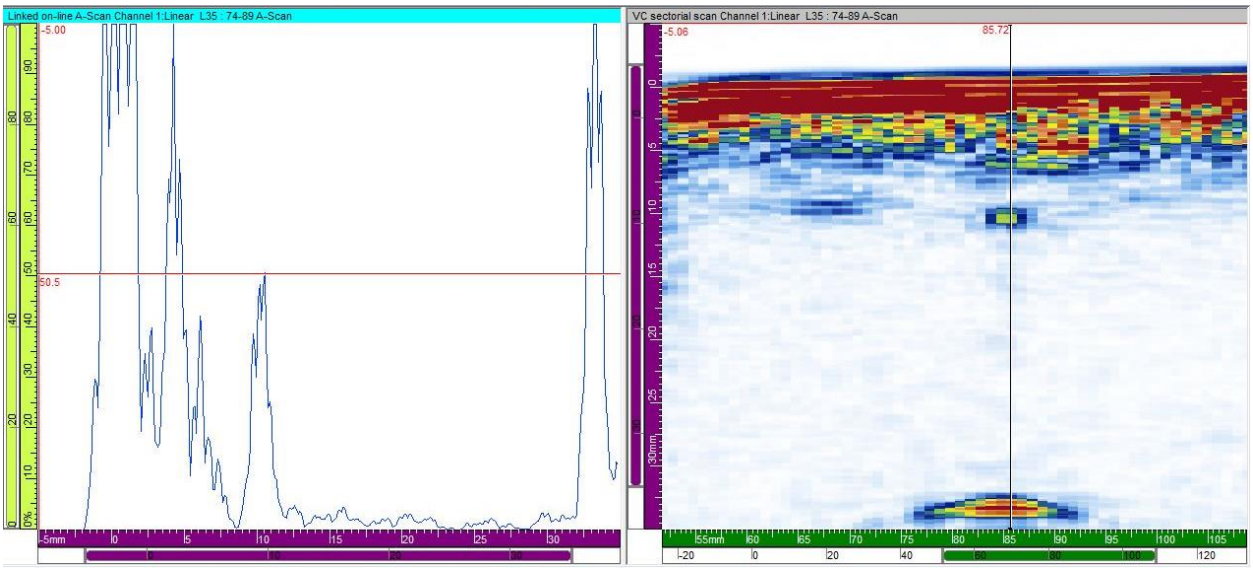
10 mm deep 1mm FBH with no DDF Simulation result

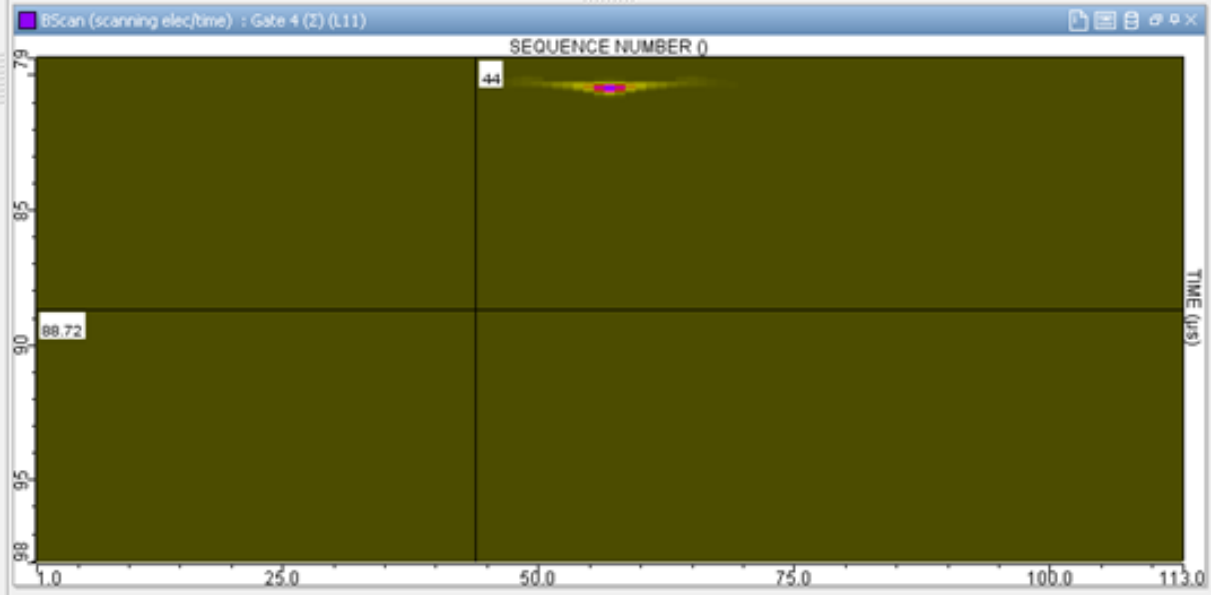


The next set of pictures shows the results of 1mm FBH at a depth of 10mm using DDF. Simulation and experimental results agree. There is marked improvement in the signal strength as can be seen in the A-Scan. The amplitude and sizing resolution are both increased.

10 mm deep 1mm FBH with DDF Experimental result

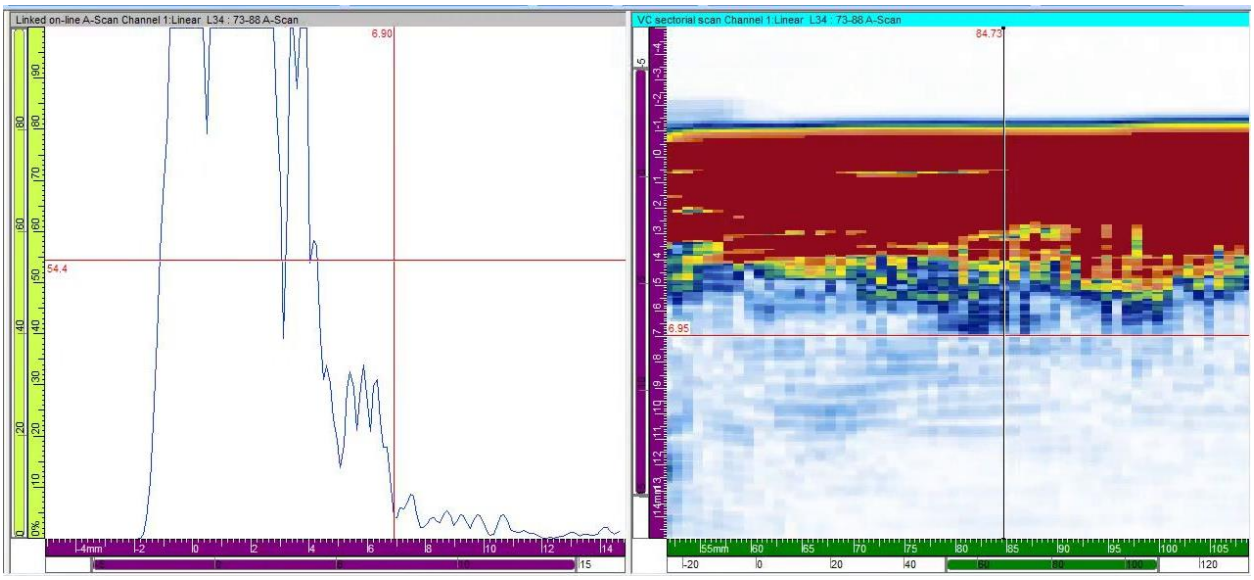


10 mm Depth with DDF Simulation result



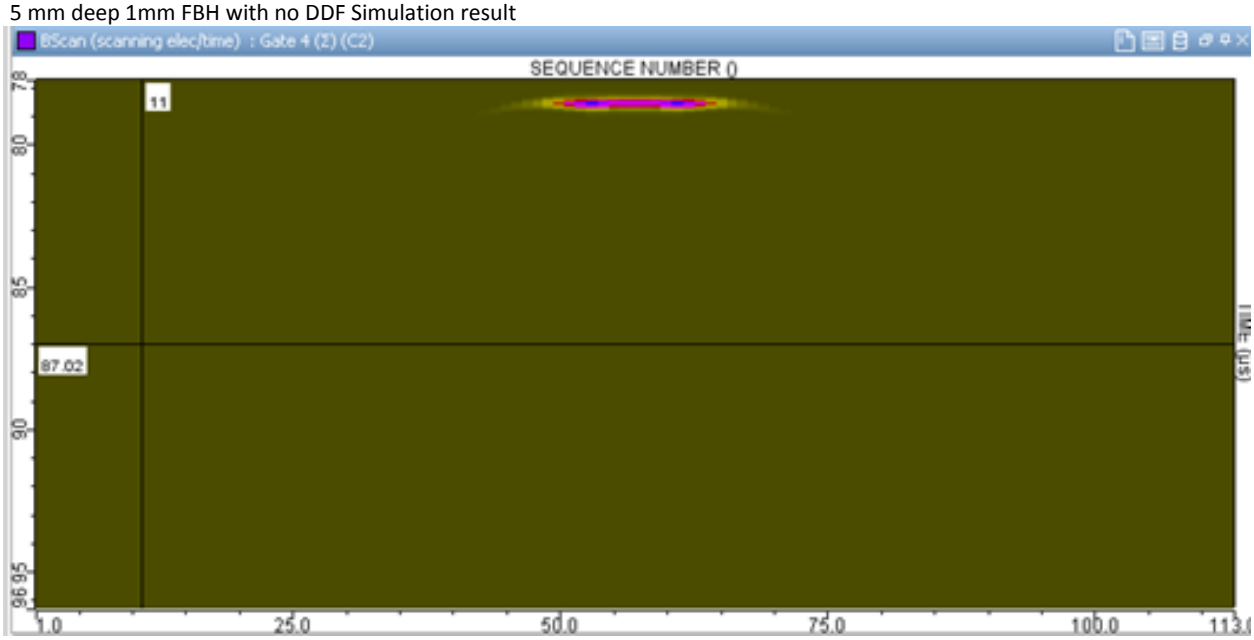
In the next set of pictures below the 1mm FBH located at 5 mm deep without any DDF is shown in the picture in the B-scan as well as the A-scan view as seen in the experiment and the next picture is the visualization of the simulation result of the same. The main point to be noted is the defect is completely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

5 mm deep 1mm FBH with no DDF Experimental result



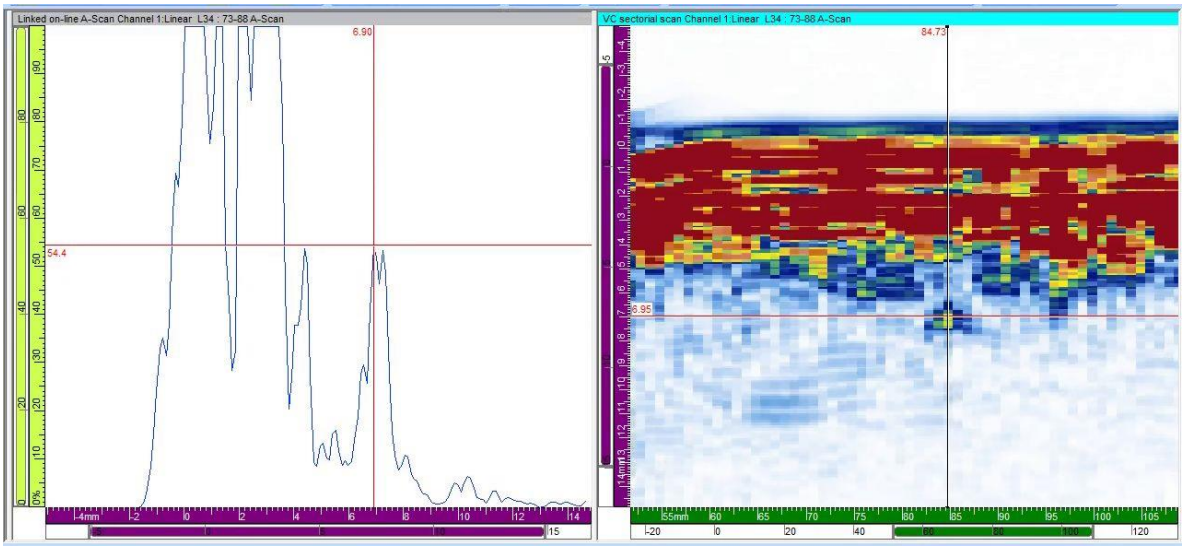
Simulation shows a result for 1mm FBH at 5 mm from the surface which shows a very spread beam with no sizing accuracy.

5 mm deep 1mm FBH with no DDF Simulation result

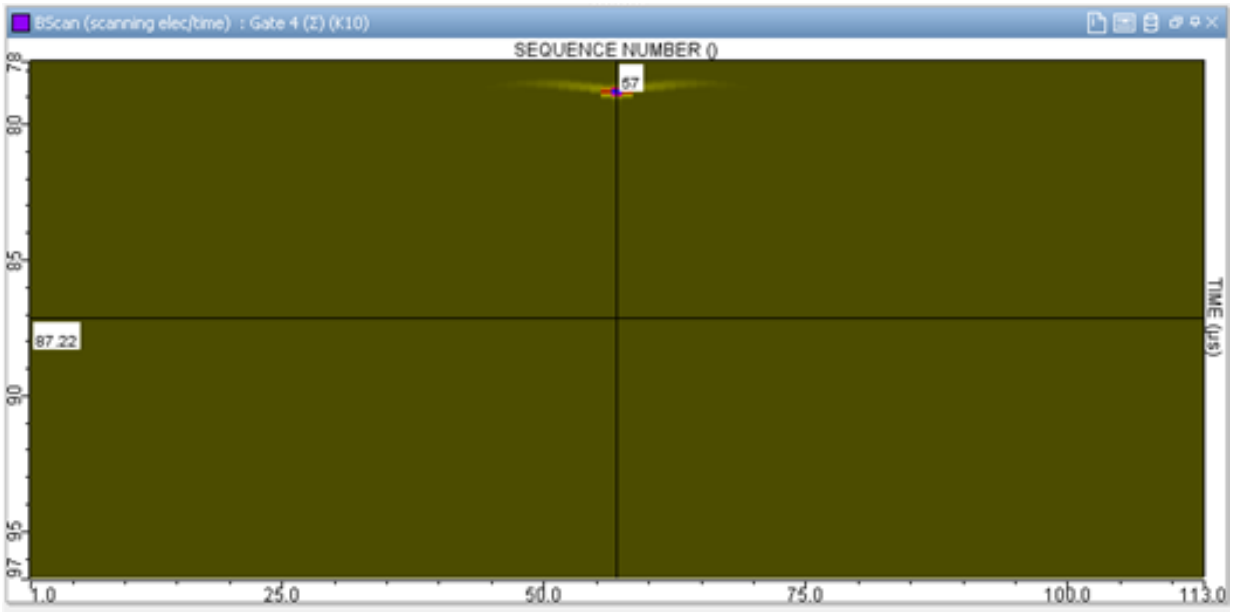


The next set of pictures shows the results of 1mm FBH at a depth of 5mm using DDF. Simulation and experimental results agree. The defect can be seen clearly and has good separation from the interface echo. There is marked improvement in the signal strength as can be seen in the A-Scan. Increasing both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

5 mm deep 1mm FBH with DDF Experimental result



5 mm Depth with DDF Simulation result



Conclusion

The data shows there is marked improvement in near surface detection capabilities both in detection and in sizing of 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 compromising on the through-put of the system.

The next step would be to experimentally study full depth of the wheel face using DDF and compare it to the simulation results.