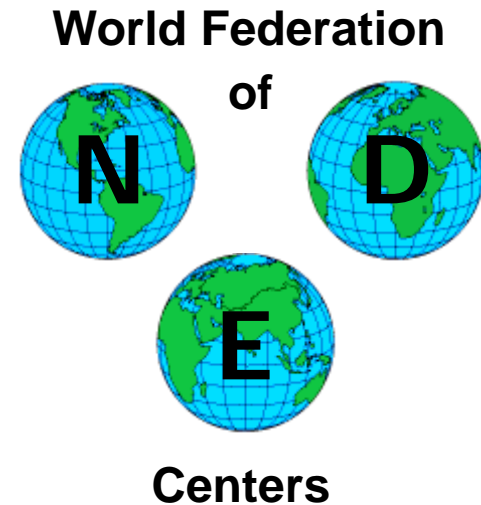


# 2009 ULTRASONIC BENCHMARKS



## Overview

In previous benchmark studies we have compared the results of ultrasonic NDE models for a series of canonical problems involving elementary flaw shapes. These comparisons have been very useful to define the level of basic agreement between the various modeling approaches, but they have not exercised or defined the full capabilities of those models.

This year, we would like to use the 2009 ultrasonic benchmark session as an opportunity to give the NDE community 1) a more comprehensive picture of the current capabilities of the ultrasonic models being used world-wide, 2) examples where the models have played an important role in more complex applications, and 3) on-going efforts to extend and improve the models.

## **PARTICIPATION IN THE 2009 BENCHMARK SESSION**

We would like to invite papers that give an overview of the current state-of-the-art in your own ultrasonic NDE modeling efforts as part of an ultrasonic benchmark session at the 36th Annual Review of Progress in Quantitative Nondestructive Evaluation (RPQNDE) meeting. This meeting will be held July 26-31, 2009 at the University of Rhode Island, Kingston, Rhode Island. To present a paper at that session, please note that the deadline for submitting an abstract is May 1, 2009 (mark on your abstract that it is for the ultrasonic benchmark session) . Also, please note that the advance registration deadline for the conference is July 3, 2009. For more details of the conference, visit the website at [www.cnde.iastate.edu/qnde/qnde.html](http://www.cnde.iastate.edu/qnde/qnde.html).

In 2004, a survey was conducted that compared the capabilities of a number of the ultrasonic NDE simulation packages then in existence. The results of that survey are enclosed with this announcement. We would like the participants in the 2009 ultrasonic benchmark session at the RPQNDE conference to complete a new survey that will be sent out as part of this year's benchmark session planning. Professor L.W. Schmerr will use this new survey data to write a summary paper in the RPQNDE proceedings that will describe how modeling capabilities have changed over the last five years as well as describe any new modeling approaches that have emerged. All participants who complete the survey will be listed as joint authors on this summary paper and have an opportunity to review its contents.

For any questions, please e-mail Prof. Schmerr at [lschmerr@cnde.iastate.edu](mailto:lschmerr@cnde.iastate.edu) .

Les Schmerr  
Permanent Secretary, World Federation of NDE Centers

## Appendix A: Ultrasonic Modeling Survey

A survey form was sent out to ultrasonic modeling groups around the world who have developed ultrasonic NDE software simulation packages. The survey was designed to obtain information on the major modeling capabilities of those software packages. The survey contained nine tables covering the following categories:

1. Modeling capabilities – transducer properties
2. Modeling capabilities – material properties
3. Modeling capabilities - scanning
4. Modeling capabilities – transducer or system spectrum
5. Modeling capabilities – sound field models
6. Modeling capabilities – reflector/ flaw scattering
7. Modeling capabilities – reception modeling
8. Modeling capabilities – outputs
9. Modeling capabilities – geometry inputs

Below are listed the responses to this survey in each of the categories. The responses are coded in the tables according to the numbers listed in front of each of the following software packages:

### 1 – UTSIM

Contact: Mike Garton

E-mail: [mgarton@cnde.iastate.edu](mailto:mgarton@cnde.iastate.edu)

### 2- CIVA

Contact: Pierre Calmon

E-mail: [pierre.calmon@cea.fr](mailto:pierre.calmon@cea.fr)

### 3a- GPSS (Generalized Point Source Superposition technique)

### 3b – GB (Gaussian Beam superposition method)

Contact: Martin Spies

E-mail: [martin.spies@izfp.fraunhofer.de](mailto:martin.spies@izfp.fraunhofer.de)

### 4 - simSUNDT (a Windows based pre- and postprocessor utilizing a modified version of UTDefect (version 3) as a kernel)

Contact: Håkan Wirdelius

E-mail: [hakan.wirdelius@chl.chalmers.se](mailto:hakan.wirdelius@chl.chalmers.se)

### 5 - UTDefect (version 4) FORTRAN code with interactive input and output lists, SUNDT (version 2, available in May, 2004) Windows version of UTDefect with graphical output.

Contact: Anders Boström

E-mail: [anders.bostrom@me.chalmers.se](mailto:anders.bostrom@me.chalmers.se), [anbo@mec.chalmers.se](mailto:anbo@mec.chalmers.se)

## 1. Modeling capabilities – transducer properties

Capability	Yes	No	Comments
<b>Transducer-element shape</b>			
circular	1,2, 3a,3b, 4,5		
rectangular	1,2, 3a, 4,5		
elliptical	1,2, 3a,3b, 4,5		
1-D array	1,2, 3a	5	1- demo version 2- linear arrays, linear arrays with circular mask, encircling array (tube inspection) 5- in the code, but not the input
2-D array	1,2, 3a	5	1-demo version 2- matrix arrays 5- in the code, but not the input
other (specify)	2, 3a		2- circular and sectorial arrays, elliptical arrays, bi-elliptical arrays ( with or without angular sectors) 3a – multiple segments with multiple elements (‘EMUS array’)
<b>Transducer-focusing</b>			
spherical	1,2, 3a,3b, 4, 5		2- with or without lens (shaped element in the latter case), same for other cases below
cylindrical	1,2, 3a, 4, 5		
bi-cylindrical	1,2,3a		
other (specify)	2, 3a		2- tri-cylindrical (3 different curvatures – two in plane of incidence, and one in the plane perpendicular to incident plane). Fermat focusing ( computation of Fermat’s surface optimizing focusing thru planar or cylindrical surface) 3a- Fermat focusing, e.g. for curved geometries

<b>Transducer -type</b>			
immersion	1,2, 3a,3b, 5		5- new – not validated
contact	1,2, 3a,3b,4		
angle beam	1,2, 3a,3b,4		
surface wave			
other (specify)	2		2 – T-R probes, tandem configurations
<b>Transducer- output velocity profile</b>			
piston	1,2, 3a,3b, 4		
other (specify)	3a		3a- as specified

## 2. Modeling capabilities – material properties

<b>Capability</b>	<b>Yes</b>	<b>No</b>	<b>Comments</b>
<b>Material -type</b>			If there are restrictions on the type of anisotropy, etc., please indicate below in the comments
isotropic solid, homogeneous	1,2, 3a,3b, 4,5		
anisotropic solid, homogeneous	2, 3a,3b, 5	1	1- model elements available for integration 5 – general in the code, only orthotropic in the input
isotropic solid, continuously inhomogeneous	3b		3b- isotropic, layered
anisotropic solid, continuously inhomogeneous	3b		3b- anisotropic, layered

<b>Material - attenuation</b>			If specific frequency forms assumed, please specify
average value (constant)	1, 3a,3b, 4, 5		
frequency-dependent	1,2, 3a,3b		2 – any frequency power law 3a,3b using model of viscoelasticity of composite material
based on microstructure model (specify)	1,2,4	3a,3b	1- CNDE model (Margetan) 2 – for fiber-reinforced composites – multiple scattering and viscoelastic losses coupled 3a, 3b – could be incorporated using an appropriate model (as in viscoelasticity, see above) 4- based on info on welding conditions, calculates size of HAZ, grain sizes in HAZ and melted areas. Uses large no. of randomly distributed inclusions to ensure central limit theorem is satisfied
<b>Material-noise (grain scattering)</b>			
rms value	1,2		
noise distribution (specify)	1,2		1-read in or specify parameters 2 – simulation of grain scattering noise by assuming randomly distributed scatterers
based on microstructure model (specify)	1	3a,3b	1-CNDE model (Margetan) 3a, 3b – could be incorporated using appropriate model

## 3. Modeling capabilities - scanning

Capabilities	Yes	No	Comments
<b>Scan-plans-motion</b>			
linear (1-D) scans	1,2, 3a,3b, 4, 5		
x-y (2-D) scans	1,2, 3a,3b,4, 5		
surface-following	1,2		
other (specify)			
<b>Scan-plans- type</b>			
pulse-echo	1,2, 3a,3b, 4, 5		
pitch-catch	2, 3a, 4, 5	1	1- implementation possible, but not current priority
thru-transmission	3a		
other (specify)			

## 4. Modeling capabilities – transducer or system spectrum

Capabilities	Yes	No	Comments
<b>Input transducer/ system spectrum</b>			Specify form used, e.g. cosine <sup>2</sup> function, etc.
center frequency, bandwidth	1,2, 3a,3b, 4, 5		1, 4 ,5 -Cos <sup>2</sup> function 3a,3b – Sin <sup>2</sup> function
experimental values (from file)	1,2,4	3a,3b, 5	3a, 3b – could be implemented 4- simple curve adaptation to a discrete no. of experimental values 5 – easy to implement, included in SUNDT
other (specify)			

## 5. Modeling capabilities – sound field models

Capabilities	Yes	No	Comments
<b>Ray-tracing model</b>			
mode-converted rays	1		
multiple surface interactions	1		
other capabilities (specify)			
<b>Beam model(s) - types</b>			If more than one model used, indicate conditions under which each are applied
Finite element			
Finite difference			
Finite integral			
Green's function - exact			
Green's function - approximate	2, 3a		2- pencil model
Angular plane wave spectrum	4, 5		4, 5 – exact and with stationary phase approximation
Multi-Gaussian	1, 3b		
Gauss-Hermite	1		1- used for rectangular probes. Will be replaced by multi-Gaussian model
other (specify)			
<b>Interface Interactions</b>			Indicate any restrictions that may apply in modeling the interactions of beams with interfaces
Planar interfaces	1,2, 3a,3b		
Cylindrical interfaces	1,2, 3a		
Other curved interfaces	1,2, 3a		1-bicylindrical 2 – CAD-designed surfaces

## 6. Modeling capabilities – reflector/ flaw scattering

Capabilities	Yes	No	Comments
<b>Reflector types</b>			For each reflector type, please indicate type of model(s) used (e.g. Kirchhoff, separation of variables, boundary elements, etc.) and any model restrictions that may apply (flaw shape, pulse-echo, etc.)
Spherical cavity	1,2, 3a, 4, 5		1, 4 ,5-separation of variables 2-Kirchhoff 3a – Kirchhoff, (pulse-echo only,including all other cases listed below)
Spherical inclusion	2,4, 5		2- original modified Born, separation of variables 4, 5 -separation of variables
Other inclusions (specify)	1,2,4, 5		1- ellipsoidal (Kirchhoff) 2- ellipsoidal, cylindrical: original modified Born 4, 5- spheroidal cavity, null field approach
Side-drilled hole	1,2, 3a, 4, 5		1,2-Kirchhoff 4 , 5 – separation of variables
Flat-bottom hole	1,2, 3a,3b, 4, 5		1,2-Kirchhoff 4, 5 – considered as circular crack
Flat crack (not at a surface)	1,2,4, 5		1-Kirchhoff 2-Kirchhoff, GTD 4, 5- circular (also partly closed), strip-like, rectangular, using singular integral eqs.
Surface-breaking crack	1,2,4, 5		1,2-Kirchhoff 4, 5 - strip-like
Surface-breaking notch	2, 3a,3b	1	1- possible with faceted model (see below) 2-Kirchhoff
porosity	2		2-Kirchhoff
Distributed cracks	2		2-Kirchhoff
Planar back surface reflection(s)	2, 3a,3b, 4, 5	1	1 – possible with faceted model (see below) 2-Kirchhoff 4, 5- in conjunction with most defects (also tilted back surface)
Curved back surface reflection(s)	2, 3a		1 – possible with faceted model ( see below) 2-Kirchhoff
Other (specify)	1,2, 5		1- arbitrary faceted shapes with Kirchhoff in progress 2-CAD designed back surface – Kirchhoff 5- only strip-like (also surface-breaking) and rectangular cracks for anisotropic solids

## 7. Modeling capabilities – reception modeling

Capability	Yes	No	Comments
<b>Reception modeling - type</b>			
Averaging fields over face of receiver			
Use of reciprocity	1,2, 3a,3b, 4, 5		
Other(specify)			

## 8. Modeling capabilities – outputs

Capability	Yes	No	Comments
<b>Type of outputs displayed</b>			
A-scan	1,2, 3a,3b, 4,5		1- currently gated signal only, no front or back surface 4,5 – only file output (graphical in SUNDT)
B-scan	1,2, 3a,3b, 4, 5		1 – currently gated signal only, no front or back surface 4, 5 - only file output (graphical in SUNDT)
C-scan	1,2, 3a,3b, 4, 5		4, 5 - only file output (graphical in SUNDT)
DAC curve –single medium	1, 3a,3b		
DAC curve – with curved interface corrections	1		
DGS diagrams		1	1- easy to implement
Other (specify)	1,2,4, 5		1- slices of volumetric data in any direction 2- echodynamic curves, rectified B-scan, D-scan, application of a large range of signal processing algorithms 4 – output files **.rdt (Tomoview) or in **.ndt (Astus) formats can be generated by the software 5 – frequency spectrum

## 9. Modeling capabilities – geometry inputs

Capability	Yes	No	Comments
<b>Geometry input methods</b>			Specify input file format(s) allowed for CAD files
Geometry defined parametrically by user	1,2,3a,3b,4,5		2- planar, cylindrical, conical, spherical, toroidal, parametric nozzles, parametric elbows
Geometry imported as CAD file	1,2		1 –IGES, STL 2-2D CAD files extended by translation or revolution, 3D CAD files, DXF, STEP, IGES formats
Other (specify)			