

Modeling and Visualization 3D Software for UT Inspection of Complex Geometries

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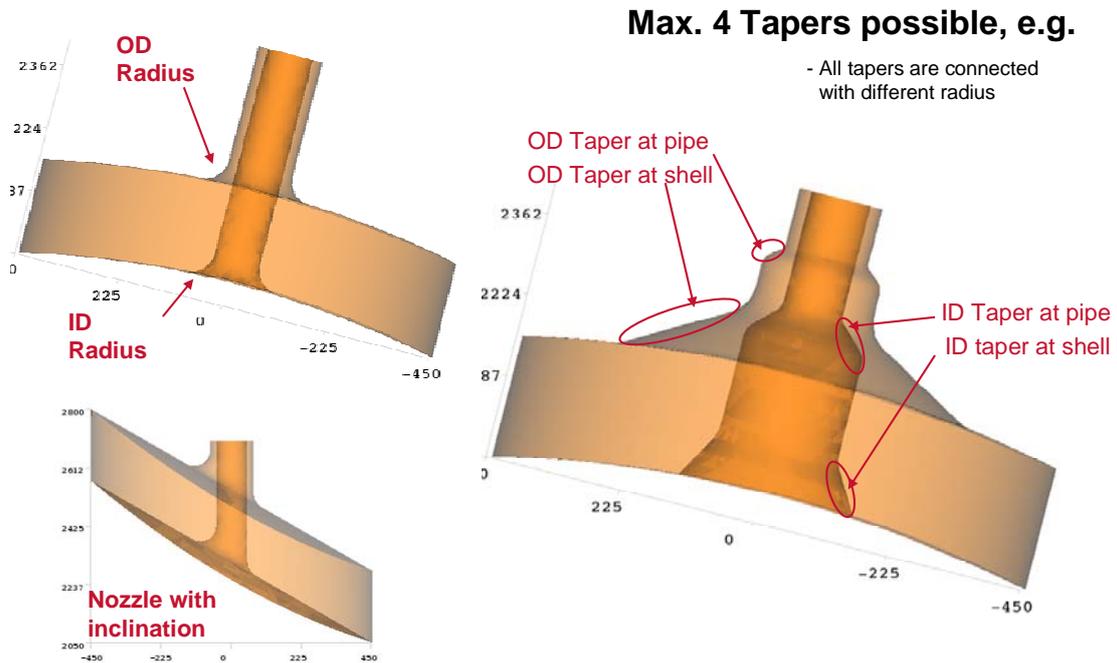
Abstract. The contract for qualification and inspection of the complete primary circuit of AREVA's Olkilouto-3 EPR requires approximately twenty six different qualifications in line with the ENIQ methodology and in accordance with Finish code YVL 3.8.

Ten of these twenty six qualification groups have complex geometries (like the nozzle-to-shell welds or the Nozzle Inner Radii (NIR)) that are not easily analyzable or verifiable using 2-D models.

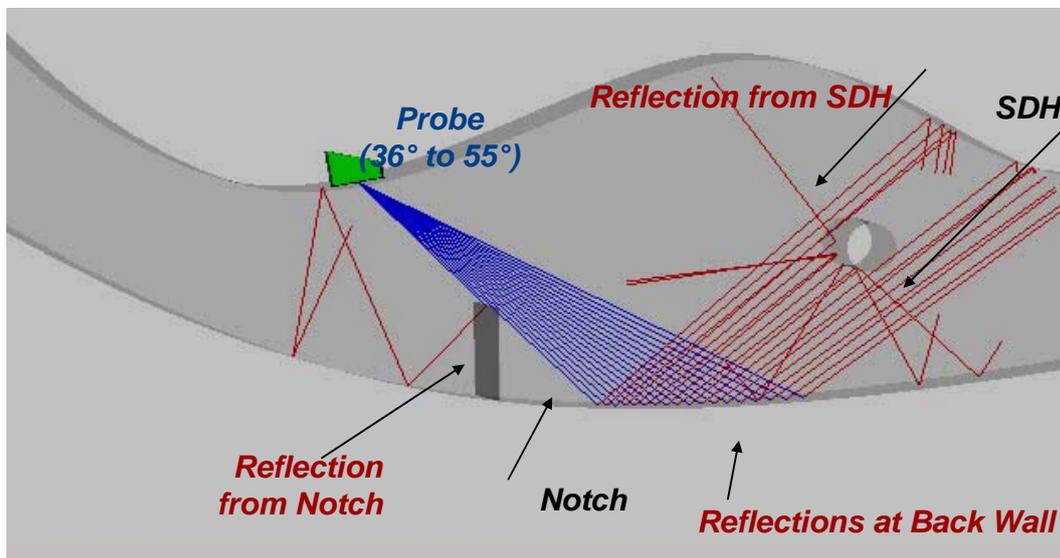
To improve costs, qualification efficiency, and verification documentation, a new universal modeling tool was developed in partnership with LUCID SW Limited (India) - the intelligeNDT Modeling and Visualization **3D-SW Tool (iMaV-3D-SW)**.

Mesh Generation

Mesh generation for most common geometries are readily accommodated directly within the iMaV-3D-SW tool. This minimizes the need for ultrasonic experts to also master 3-D CAD tools. Example shapes include cylinder-cylinder geometries (like Reactor Pressure Vessel (RPV) shell intersection with primary pipe nozzles) or sphere-cylinder geometries (like the pressurizer lower dome intersection with the surge line). The code's flexibility includes inclination and offset of the centre to the main component plus up to 2 tapers for the ID and 2 for OD, as well as blending radii.



If the geometry is not readily modeled with the internal mesh-generation functions, essentially any shape may be developed using traditional 3-CAD software like AutoCAD or Solid Works. The CAD models are then imported into the **iMaV-3D-SW** tool where the UT model interactions may then be analyzed.



Manual UT Model Mode

In the manual mode, forward (from probe side) and backward (from defect side) UT beam visualization is possible. Specified parameters include the probe position, beam angle, skew angle, sound path, and the number of skips allowed against the geometry surfaces. Beam visualization includes not only the central beam but also the fan and cone rays relative to the central beam. Other important parameters like the beam angle, mis-orientation angle are also factored into the display of the complete sound path originating from the probe transmit location to any geometry or surface reflectors then continuing to the receiving transducer.

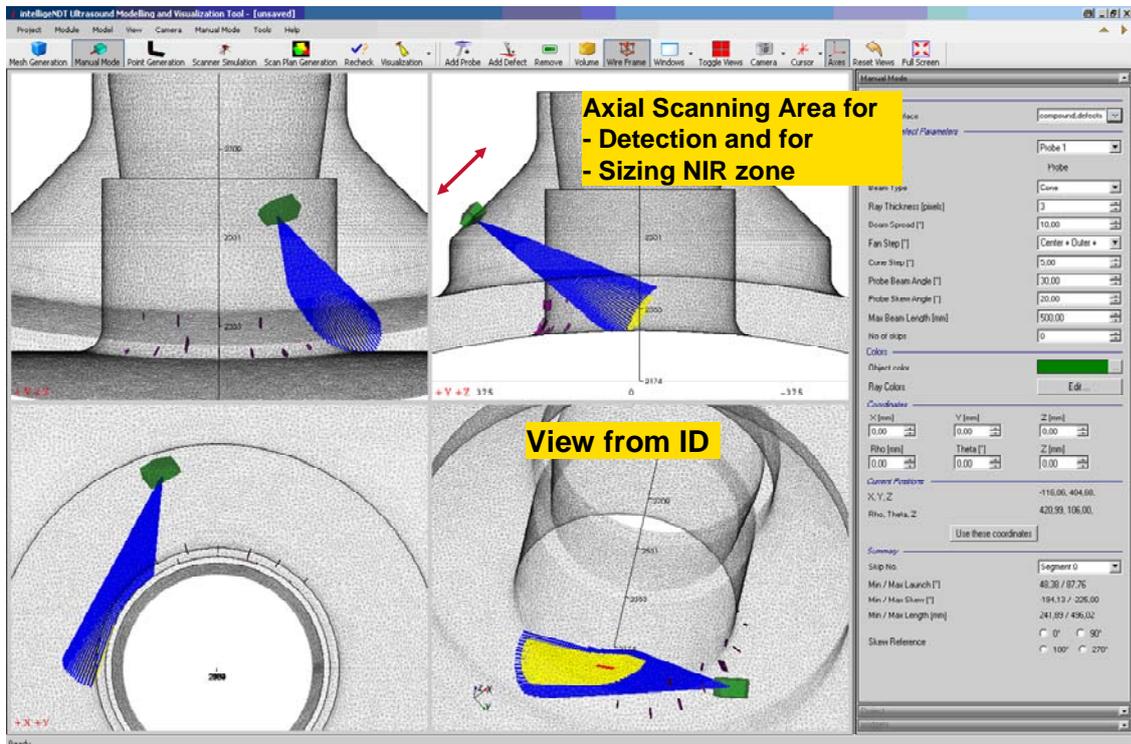


Figure 3: Visualization of cone beam in manual mode

Point Generation

Examination volumes (defect areas of concern) and scanning areas can be defined in the point generation mode. Here, inspection parameters like defect size and index/trigger grid density can be specified. The examination and scanning area can be chosen on any surface of the component including ID, OD or both ID and OD.

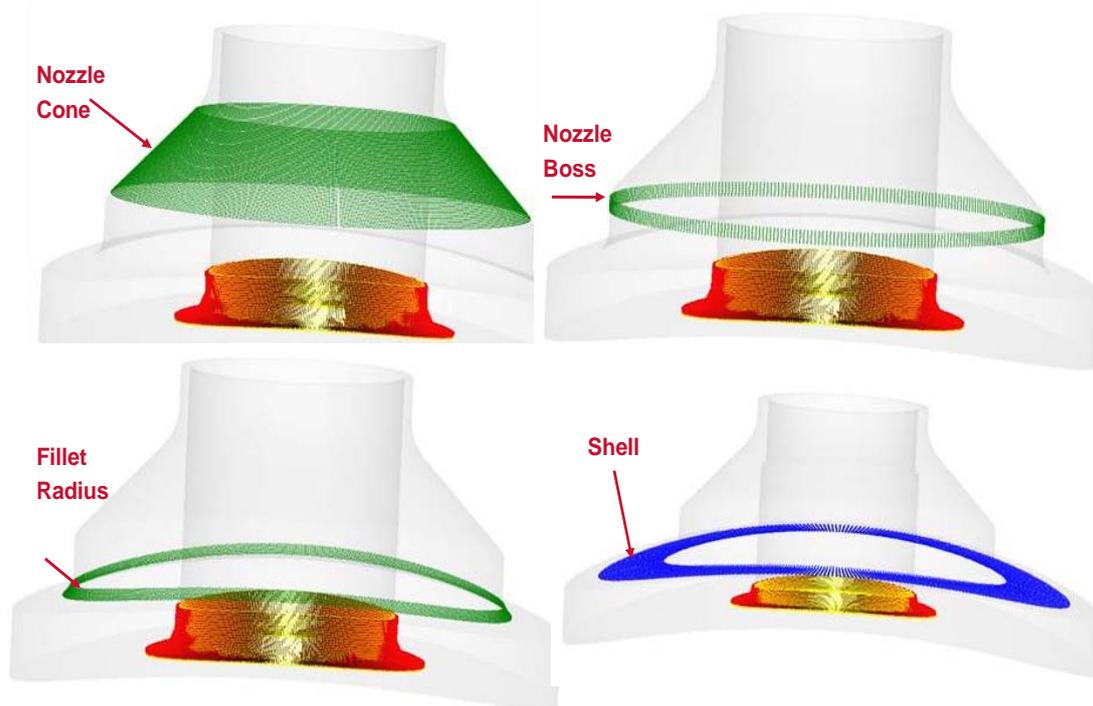


Figure 4: Definition of different scanning areas at SG FW Nozzle

Scanner Simulation

The scanner simulation module visualizes probe movement and coverage with a defined beam and skew angle in the given scanning area. The parameters at the first skip impact point are displayed during the scanning simulation.

Scan Plan Generation

Considering the available scan area and inspection volume (defect area with a given defect size and orientation), the mis-orientation of the beam (skew angle) and the beam angle at the postulated defect are calculated in the scan plan generation for a given value or range of defined probe skew and probe beam angles (applicable to either conventional or Phased Array techniques).

For the required data input, investigations into "allowable" mis-orientation and beam angles at postulated defects have been performed by making measurements on a number of defects of various size (length & TWE), tilt and skew at different sound paths for different Phased Array UT-techniques (single and dual crystal, crystal size and frequency). These measurement results were compared also with the theoretical results given by CIVA SW.

The results of the scan plan generation can be presented in a table, as a 2 dimensional roll-out, or directly in the 3-D model.

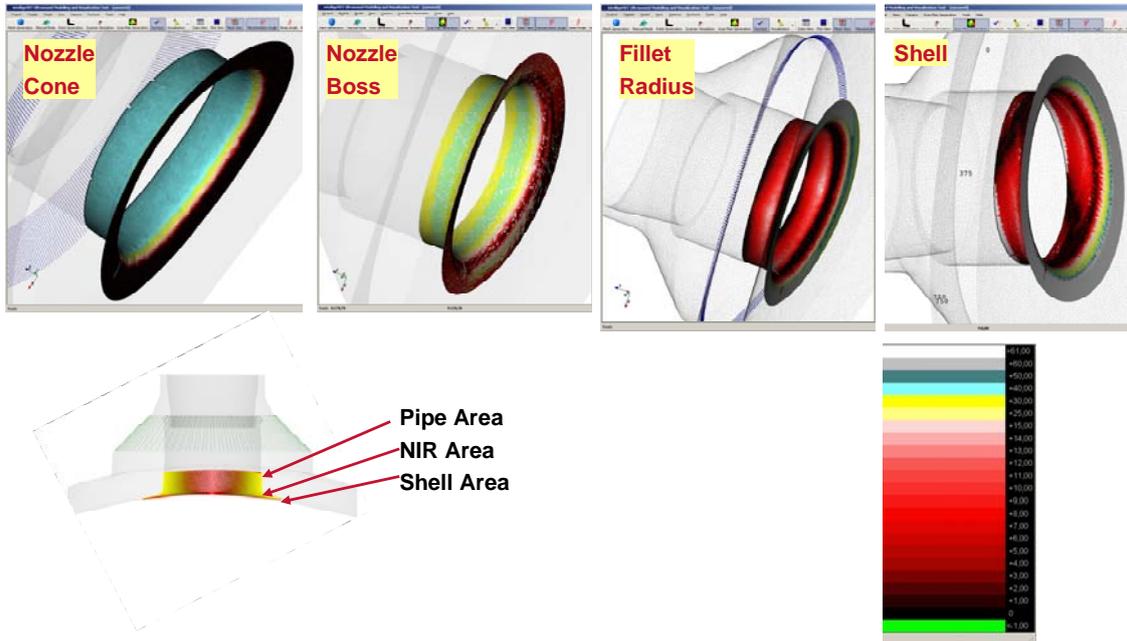


Figure 5: Representation of mis-orientation for different scan areas

These presentations can also visualize the sound path to the defect and the coverage achieved.

Depending on the capability of the manipulation and the UT probe, the usable beam and skew angles can then be selected. Hereby, matrix arrays, linear arrays or conventional (single beam angle), with or without mechanical skewing, can be defined.

Re-Check

The re-check module shows the expected inspection quality over the examination area for the final chosen parameters including beam spread and skew angles.

3-D Visualisation

A very detailed verification of the iMaV 3-D SW Module was done for the SG FW Nozzle geometry. For this geometry, the theoretically calculated parameters using the iMaV 3-D SW Module were used for the UT inspection from the OD on a 1:1 test block with implanted defects in the inner radius region. The acquired UT data can be visualized in the 3-D Model where positioning and length & TWE sizing are performed. Known defects can also be integrated in the 3-D Model for visualization and comparison of the UT-measurements with the actual defects contained in the test block.

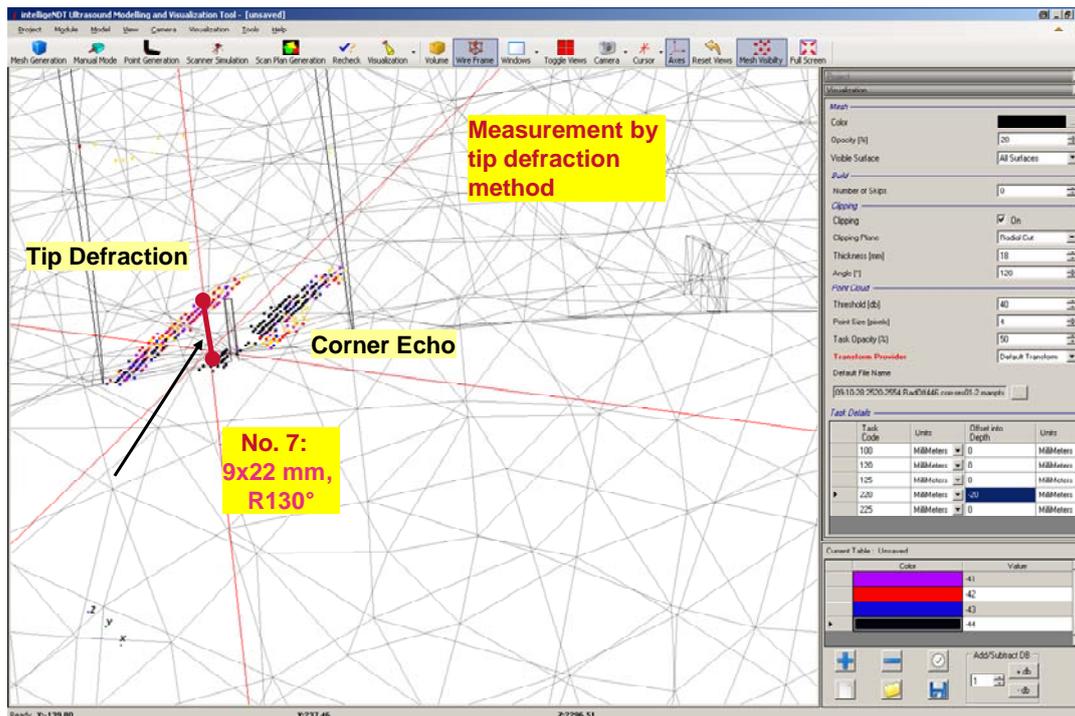


Figure 6: Through-Wall-Extent (TWE) sizing

The experimental results on numerous sample geometries were used to verify the iMaV 3-D SW Module's UT beam prediction accuracy. All complex examination areas of the EPR primary circuit were then investigated using the iMaV-3D-SW-Tool.

The modeling tool can be used for any complex geometry and from any scan surface or defect volume of interest. For these difficult-to-inspect geometries, the modeling tool can be invaluable; both at the crucial inspection design stage, and also in generating the theoretical evidence often required by a qualification process such as ENIQ.

The modeling tool has also been used outside the power industry, for example, including one oil company complex geometry inspection challenge.

Coordinate Transform Module

For transformation of 2-D manipulator positions with a third degree-of-freedom spring loaded movable probe holders designed to track a complex geometry, a transform module is integrated in the 3-D-Visualisation to incorporate the known part geometry. This tool transforms the measured UT-data plus the 2-D coordinates into the 3-D component giving the actual (true) location of the data within the component.

This feature was used for the RPV NIR qualification with inspection from the ID.

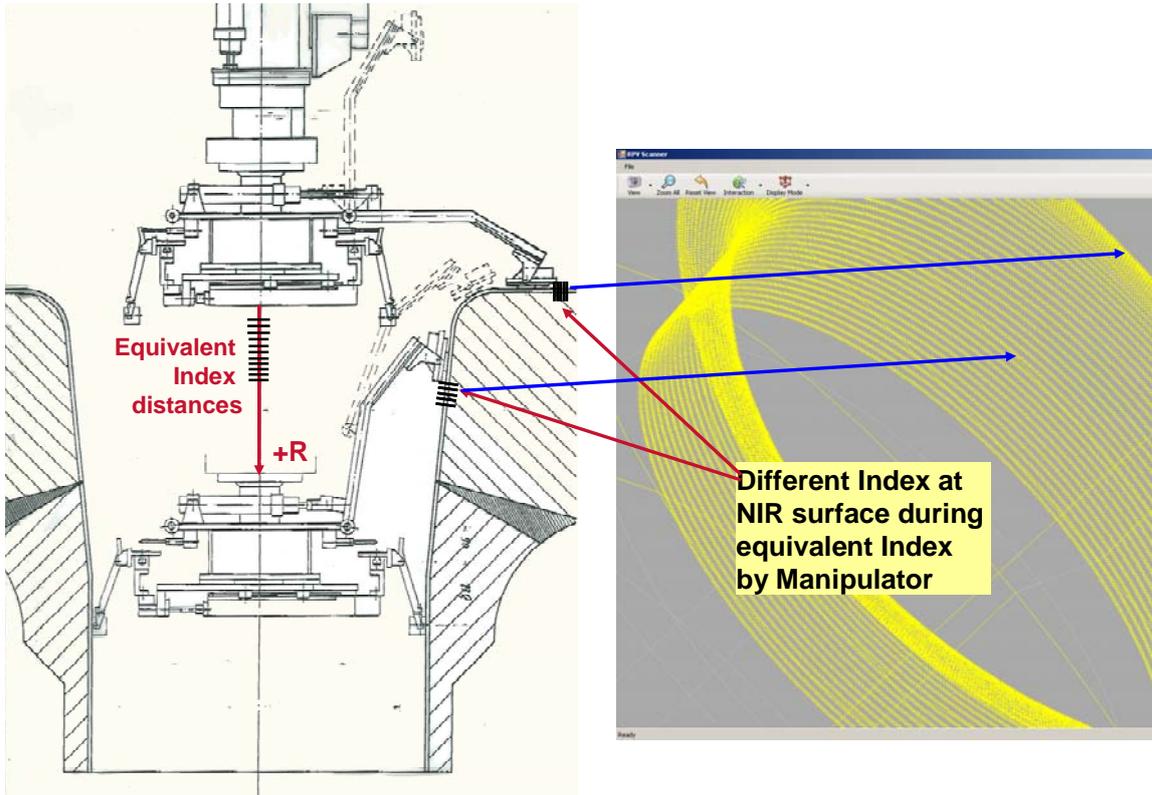


Figure 7: Coordinate transform from 2-D scan manipulator to 3-D image

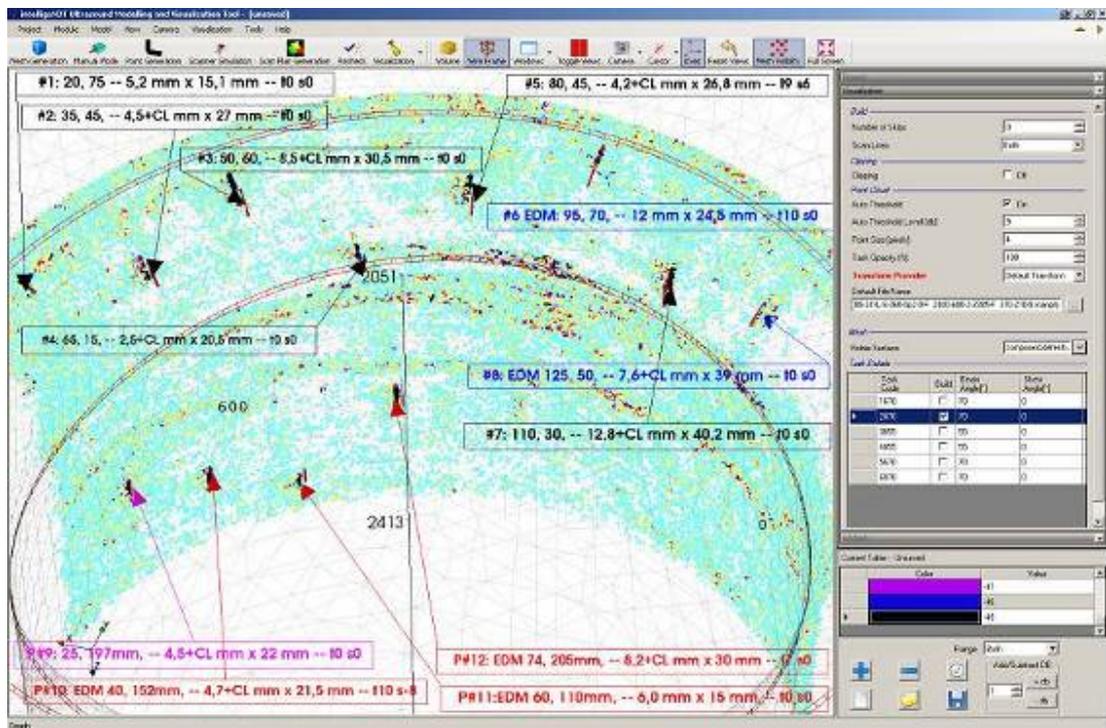


Figure 8: 3-D Visualization with "as build flaws"

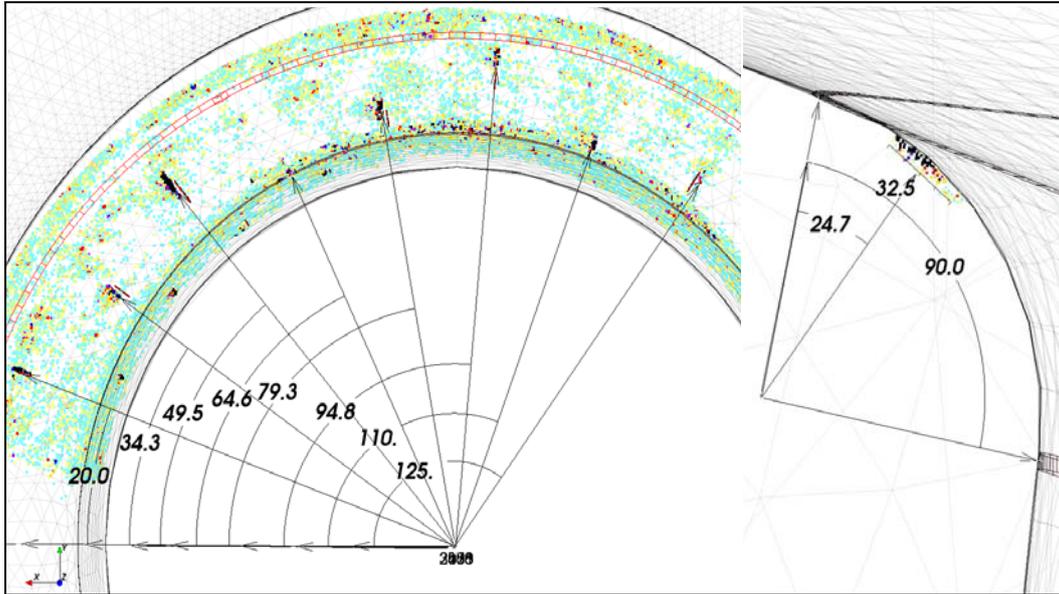


Figure 9: Positioning and length sizing by 3-D Visualization

Examples for Using Integrated CAD-Interface

One example for using the integrated CAD-interface is the visualization of possible way scanning surfaces. Herby the SW can calculate the gap below a postulated probe footprint.

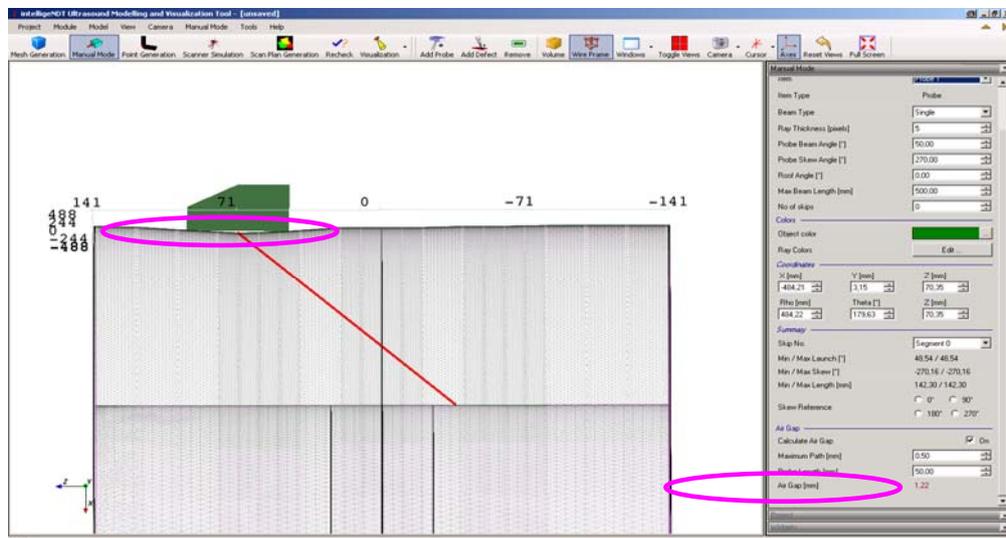


Figure 10: Calculation of Gap below UT-probe Housing

Furthermore by visualization of the actual UT data, the acquired amplitudes will be shown on the correct location by considering the actual surface geometry for the beam angles.

One example for non nuclear components using the integrated CAD-interface is the optimization of inspection techniques for rail discs. Based on the complex disk geometries the visualization of the postulated beams is quite helpful:

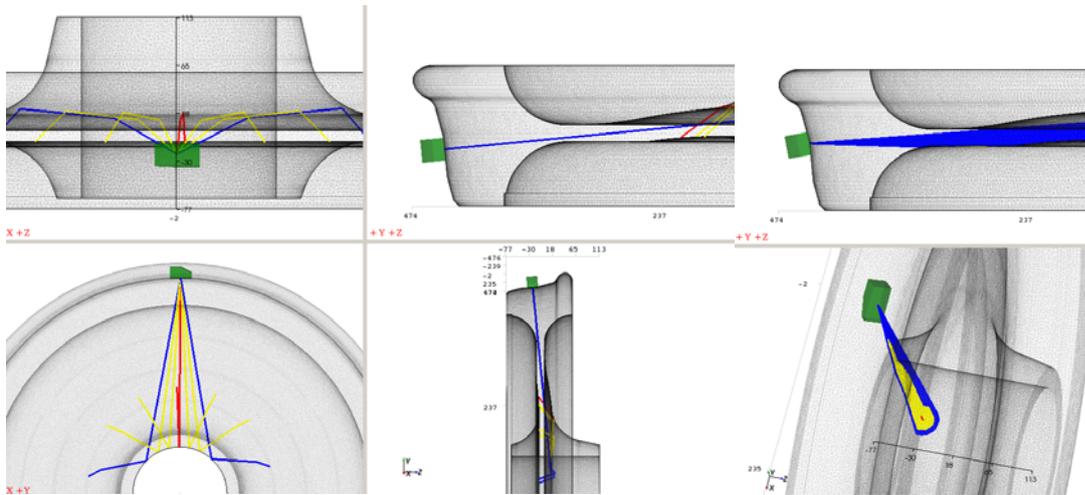


Figure 11: Beam Modeling for rail discs in 3-D Visualization

Summary

With the development of the iMaV-3D-SW-Tool, an intuitive, usable software tool for modeling and true 3-D visualization of predicted and the measured data is now available. Using the tool, inspection modeling and visualization can be applied to any (not just complex) geometry with available scan areas to access the target inspection volume.