INTERACTIVE SOFTWARE TOOLS FOR INSPECTION QUALIFICATION

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ABSTRACT. The demonstration of ultrasonic inspection reliability through Inspection Qualification is important for non-routine or safety critical tests. However, since Inspection Qualification is time consuming and costly, the provision of interactive software tools to aid the process offers substantial advantages. This paper describes such an interactive tool set to aid Inspection Qualification. Operating within a 3D CAD environment it consists of ray tracing, coverage map and defect/ray interaction tools. Initial ray amplitudes are also calculated and displayed, and estimation of favorable surface scanning positions determined.

INTRODUCTION

Inspection Qualification tends to be carried out where component integrity is essential for safety or in cases of non-routine geometries. A key element in this process, as developed by the European Network for Inspection Qualification (ENIQ), is to produce a Technical Justification which documents evidence that a testing procedure would detect established worst case defects present within the examined component. The Technical Justification details all the information relating to the testing procedure and combines evidence from physical reasoning and simulation models linked to experiments on test pieces. This builds up to a sizeable document that is time consuming and costly to produce.

This paper describes an interactive software toolset that can aid the process of inspection design and provide a speedier means of producing evidence for Inspection Qualification. The first of these is the ray tracing tool, which allows the user to track the path of the ultrasound within the component. Following on from this is the coverage map tool which establishes the volumetric coverage achieved during the scan. Also incorporated is the defect/ray interaction tool which provides feedback on defect/ray incident angles achieved during the scan. In addition, predictions of ray amplitudes are determined. And lastly, back projection of normal rays from hypothetical defects are established. These tools will aid the NDT engineer in designing ultrasonic tests and assist him in collecting proof that the tests are fit for their intended purpose.
SOFTWARE PLATFORM

The tool set operates within a software platform [1] designed using Visual C++ and using OpenGL for the graphical display. The software contains a number of scalable CAD geometries that are represented by facets. Strip like, circular and elliptical facets can be inserted into the components to represent possible defects. Figure 1 shows two geometries with defects inserted.

RAY TRACING

The ray tracing tool displays rays that represent the path of the ultrasound within the component. Both a selected dB-down contour of the beam and the beam axis are represented, in one principal plane of the beam. This tool can be used to emulate a scan of the component. To execute a ray trace there are two options within the software for setting up the scan.

The first option requires the user to select a component surface, a scan origin and scanning increments in the primary and secondary directions; for a flat plate the primary and secondary directions would normally correspond to the x and y axes of the component.

The second option is to design an algorithm, or 'geometry code'. This approach is used in industry to establish the exact positions of the probes on the component surface, given the coordinates of the controlling manipulator. Both these options are suitable for flat scanning surfaces, but in the case of curved surfaces, geometry codes are employed to overcome the inaccuracies of the faceted surface representation of the component. Figure 2 illustrates ray tracing within a pipe component. The mainbeam and the upper and lower extents of the 6dB beam width are represented by colour coded rays.

Striplike, circular and elliptical defects can be inserted into the component and the defect properties - rotation (orientation), skew, tilt, position and size - can be altered through the defect dialog. The defect dialog for the strip-like defect is shown in Figure 3. The defect orientation, tilt and skew can also be altered using defect selection dials,
shown in Figure 4, and the defect can also be moved to the required position by dragging with the mouse.

FIGURE 2. Ray tracing within a pipe component.

FIGURE 3. Defect dialog for the strip-like defect.
FIGURE 4. Defect dials.

COVERAGE MAPS

Without reference to any hypothetical defect, coverage maps define the volumetric coverage achieved within a component by scanning with the probe. Within the Technical Justification, coverage maps are produced for each probe to be used to demonstrate that full coverage of the volume of interest is achievable. The coverage mapping tool utilizes information from the ray trace of the scan. It operates by voxelising the component into $1\text{mm}^3$ voxels; if a voxel is ‘hit’ by the beam, then that voxel is tagged and assigned a flag. This provides a method for determining probe beam coverage in 3D for the Technical Justification. At present this information is in 2D and is calculated ‘by hand’. Figure 5 illustrates the output from the coverage map tool when a flat plate, with an excavated section above the weld area, is scanned using a $70^\circ$ probe. The figure shows the effect of reflection from the face of the excavation, together with colour-coding to indicate coverage by the beam axis and the leading and trailing beam edges. In this instance a small section of the weld area, below the excavated section, is missed during the scan.

FIGURE 5. Example of coverage map display for a $70^\circ$ probe scan of a flat plate.
RAY TRACING TOOLS FOR DECISION SUPPORT

Technical Justification documents may presently include results from full simulation modelling and evidence from experimental test blocks. It may not be necessary to produce extensive evidence at this highest level if the ray tracing tools can, through physical reasoning, establish a worst-case defect and demonstrate its detectability. To this end, the tool presently establishes the incident angle of the ray with respect to the defect normal and allows prediction of ray amplitudes along the ray.

Defect/Ray Interaction

The defect/ray interaction tool allows the user to establish the incident angles of the beam axis ray with respect to the defect normal during the scan. This tool utilizes information from the ray trace of the scan and results are displayed as a colour coded map on the defect face, for incident angles from 0° to 90°. Figure 6(a) shows a strip-like defect inserted into a pipe wall. The output from the defect/ray interaction tool is illustrated in Figure 6(b). In future there will be an option to display this information numerically.

Amplitude Prediction

It is also possible within the software to calculate amplitudes at positions within the beam. This has been done by incorporating validated beam modelling algorithms [2] for single crystal probes. In the final application, this information, along with the incident angles for the scan will form an input to some kind of rule. This rule will consider the measure of incident angle and amplitude to decide whether the defect is probably detected, or whether further, more detailed modelling, is required.
An additional tool to aid the engineer allows projection of normal rays from the extremes of a hypothetical defect to the inspection surfaces, to show over what extent of the scan it is possible to achieve normally incident rays on the defect. These rays can then be interrogated to establish the probe angles required to achieve specular reflection from the defect. Figure 7(a) shows projection of normal rays from a strip-like defect inserted into a flat plate. This tool may prove particularly useful for designing inspections for components with curved surfaces, where the normal rays intersect the surface at varying angles; Figure 7(b) shows the case of a circular defect inserted into a pipe wall.

CONCLUSIONS AND FURTHER WORK

Our plans are to expand on this work by mapping visual information to the defect face relating to the dB-down incident beam amplitude achieved during the scan. We also intend to include information regarding the location of diffraction ‘glint’ points on defect edges, along with their maximum incident dB-down beam amplitudes. It is hoped that the knowledge obtained can be used as an input to a rule base that determines whether the defect can immediately be classed as detectable or if further modelling needs to be carried out.

In conclusion, progress has been made in demonstrating that interactive software tools can aid the process of ultrasonic test design and Inspection Qualification. The visual display assists the user in understanding the physical reasoning of the tests. In addition, the time needed to analyze the performance of a testing procedure and produce evidence for the Technical Justification is greatly reduced, thus decreasing the cost.
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REFERENCES