3D Synthetic Aperture Imaging Using a Water-Jet Coupled Large-Aperture Single Transducer.

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Abstract: In this paper we present a technique that uses a transducer that focuses the sound at the surface of the sample, thus generating a diverging sound field within the sample. The novelty is in successfully applying the Virtual Source (VS) concept using water jet coupling for a large transducer. By focusing the sound field, the water jet probe can be built with a small nozzle opening, limiting the water consumption and making it viable for field applications. The annular geometry of the large transducer ensures the diverging spherical wavefront in the medium, assumed in the application of the SAFT algorithm, which usually limits the size of the transducer.

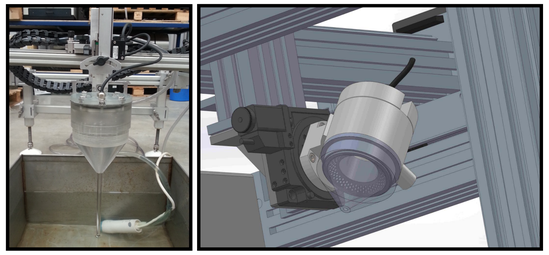
1. Introduction

- The goal is the Nondestructive Testing of railway crossings made of high manganese steel using ultrasound.
- Manganese has a coarse-grained structure and anisotropic properties.
- The Synthetic Aperture Focusing Technique (SAFT) has been selected due to:
  - Dynamic focusing with uniform resolution at any depth.
  - Ability to obtain a 3D reconstruction.
  - Grain noise is reduced through spatial averaging.

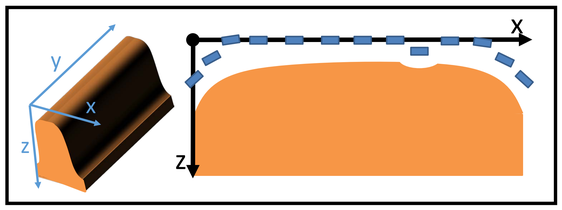
Section of a railway crossing.

2. Experimental Setup: Water-jet coupling with annular transducer array

- A large transducer improves the SNR but reduces the spatial resolution due to averaging effects over the transducer area.
- A small transducer will increase resolution and also provide a wider aperture. The SNR is however decreased.
- Using an annular array to focus the sound field from a large-aperture transducer at the surface of the sample, we obtain a Virtual Source (VS) with high energy, but with a diverging sound field inside the medium
- A water nozzle has been designed to couple the ultrasound during field tests. The focusing of the ultrasound at the surface allows to build a narrow nozzle with low water consumption (1-2 liters/min).
- To adapt to the profile of the crossing, the transducer is vertically displaced and rotated, leading to a better coupling.



Transducer mounted on the scanner and encapsulated in a water nozzle.



Nose of the crossing (left). Illustration of the transducer movement across a section of nose o the crossing (right).

3. Synthetic Aperture Focusing Technique (SAFT) for ultrasound imaging

- In SAFT, a synthetic focus is obtained in the post-processing of the pulse-echo signals acquired by scanning with a single-element transducer.
- The traditional SAFT algorithm had to be compensated for the following effects:
  - Rotation of the transducer.
  - Vertical displacement of the transducer.

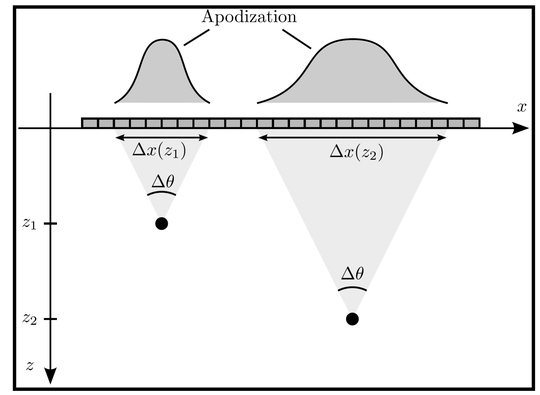
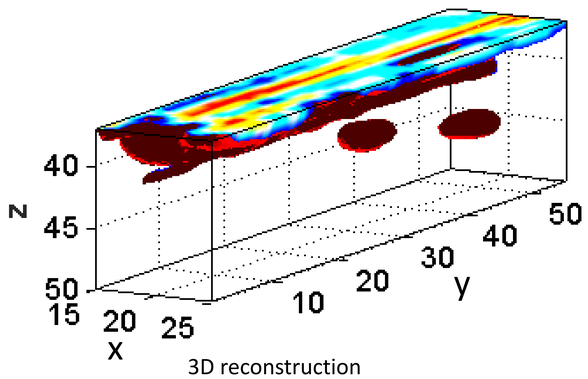


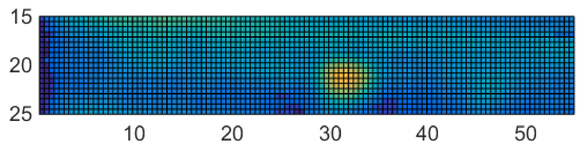
Illustration of the synthetic aperture focusing concept. Figure obtained from [1].

4. Experimental Results

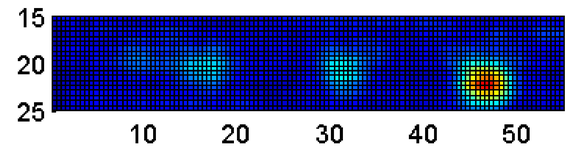
- A test was performed on a manganese with 3 flat-bottom bottom drilled holes and 27 mm of water path.



3D reconstruction



2D slice of the defect at 42.5 mm.



2D slice of the defect at 44 mm.

5. Conclusions

- A experimental setup for imaging using SAFT has been presented with a water jet coupling and a focused transducer.
- The system operates at 2.5 MHz and uses only 1-2 liters of water/minutes, making usable in field tests.
- The SAFT algorithm was adapted to account for the vertical displacement and rotation of the transducer.
- Immersion tests have been performed in manganese samples with successful 3D reconstruction.
- These results form a proof of concept for the in-site inspection of manganese rails with water jet coupling.

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