A novel approach to the in-service inspection of bulk tanks in ships

Non-invasive Monitoring of Ships for Corrosion using Ultrasonic Guided Waves

The 'ShipInspector' project

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Project aims:

This project set out to develop an enhanced method of detecting corrosion and cracking in ships, which would result in a more cost-effective means of ensuring leak-tightness of tanks in tanker vessels. The three Classification Societies participating in the project, Lloyds Register of Shipping, American Bureau of Shipping-Europe and Class NK, identified a specific need for the detection of corrosion in the floors of bulk tanks in ships. Inspection by surveyors is generally only possible when a vessel is docked for inspection and maintenance so that internal examination is infrequent. The issue of inspection is more acute for FPSO vessels which rarely leave station and for which leakage of oil from on-board tanks poses severe problems for both the environment and for production. The objective of this project was to develop ultrasonic phased array techniques, sensors and systems for finding such defects in critical areas of ships and tankers without taking the vessel out of the water.

The 'Shipinspector' project focused on the use of long range, low frequency ultrasound to provide a continuous monitoring capability for large areas of the tank floors so that progressive degradation from corrosion and cracking could be identified at an early stage. The aim is to reduce the cost of ensuring that the tanks are free from metal loss due to corrosion, which could cause the tanks to leak and release the oil or hydrocarbon products into the sea.

The area to be examined is the internal floor of the cargo tanks, where water and other contaminants may collect under the hydrocarbon cargo and cause corrosion. This is illustrated in Figure 1. Inset may be seen an isolated corrosion pit in an otherwise well painted surface. This is a worst-case scenario, as a single pit may cause a leak from the tank.

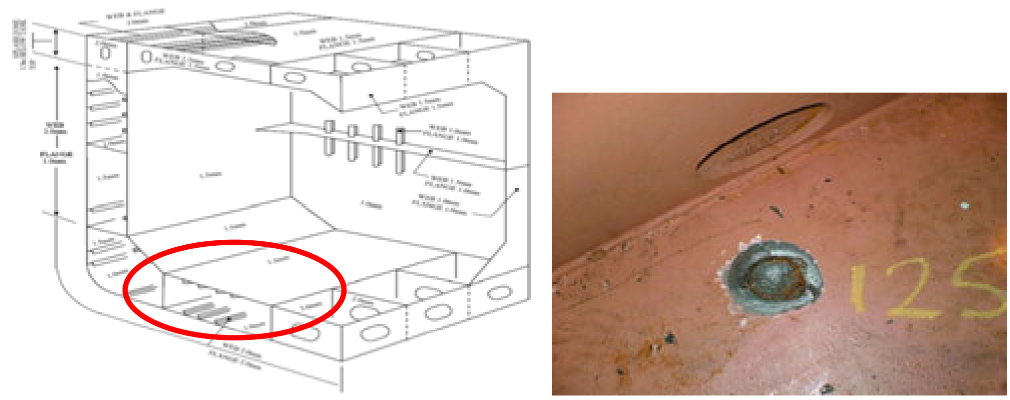

Figure 1. Tank floor plating to be examined and a severe isolated corrosion pit.
(*Images courtesy of American Bureau of Shipping*)

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The requirement to detect a single corrosion pit was used to set the performance target of detection of a circular patch of corrosion 40mm in diameter and ½ the plate thickness deep.

Monitoring Method

Low frequency ultrasound, just above the audible range, may propagate long distances in metals as so-called guided waves. The upper and lower boundaries of the plate limit the transmission of energy out of the plate, so that it acts as a wave guide. Use of transmitting transducers which are small compared with the ultrasound wavelength allows the waves to be transmitted in all directions from each transducer. Figure 2 shows a finite element analysis (FEA) model of the propagation of guided waves in a stiffened plate.

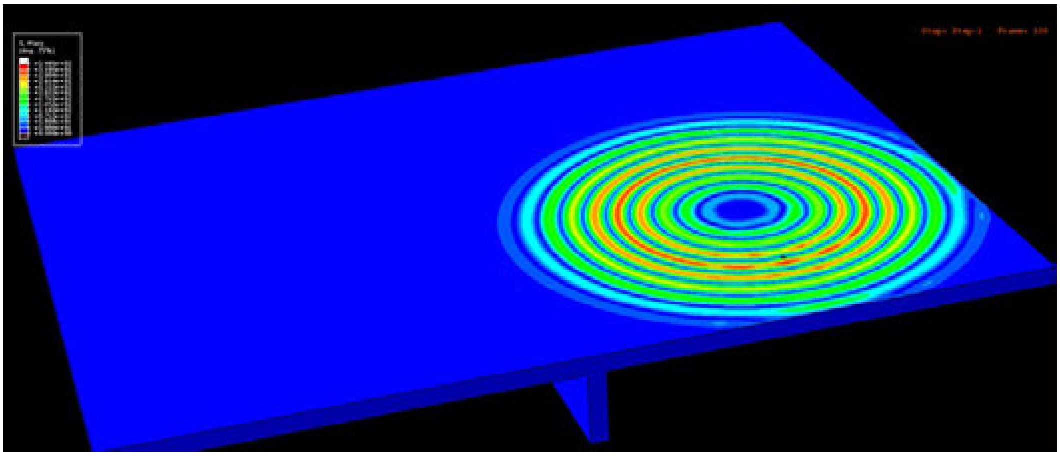

Figure 2. Ultrasonic guided waves propagating from a point source in a stiffened plate.

A network of sensors allows a very large area to be examined thoroughly. This is necessary, as the area of the floor of a tank in a VLCC or ULCC may be as large as 1,000 m^2. Figure 3 shows the proposed sensor arrangement.

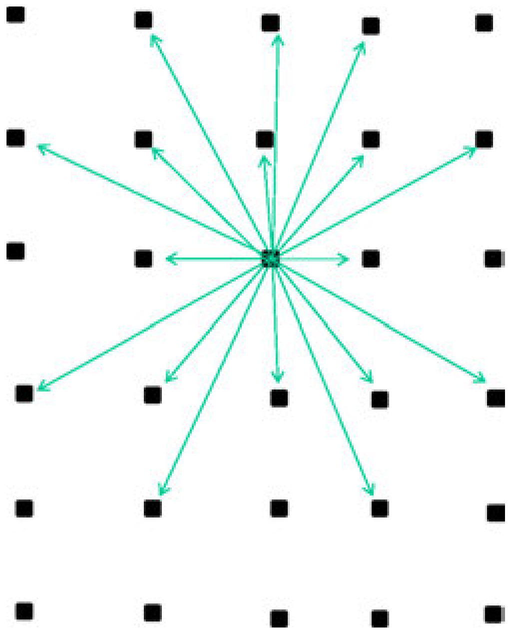

Figure 3. Proposed sensor network for monitoring of tank floors. One senor is shown transmitting with many receiving the signals. This may be repeated for each transmitter.

The strategy adopted to enable degradation to be detected is to monitor the floor by energising the sensors frequently, so that trends in the data may be used to determine the presence and growth of corrosion or cracks. This requires that the test system is stable with time and that the factors affecting the stability of the results are known and accounted for. Experiments were carried out on a large plate specimen, 12m x 6m in size and 20mm thick, to represent the plate thickness used in cargo tank floors in VLCC vessels. This is shown in Figure 4.

Figure 4. 12 x 6m plate specimen with stiffeners used for experiments for floor monitoring

Transducers were placed in 24 pairs around the edge of the specimen to simulate the arrangement shown in Figure 3. The positions are shown in Figure 5.

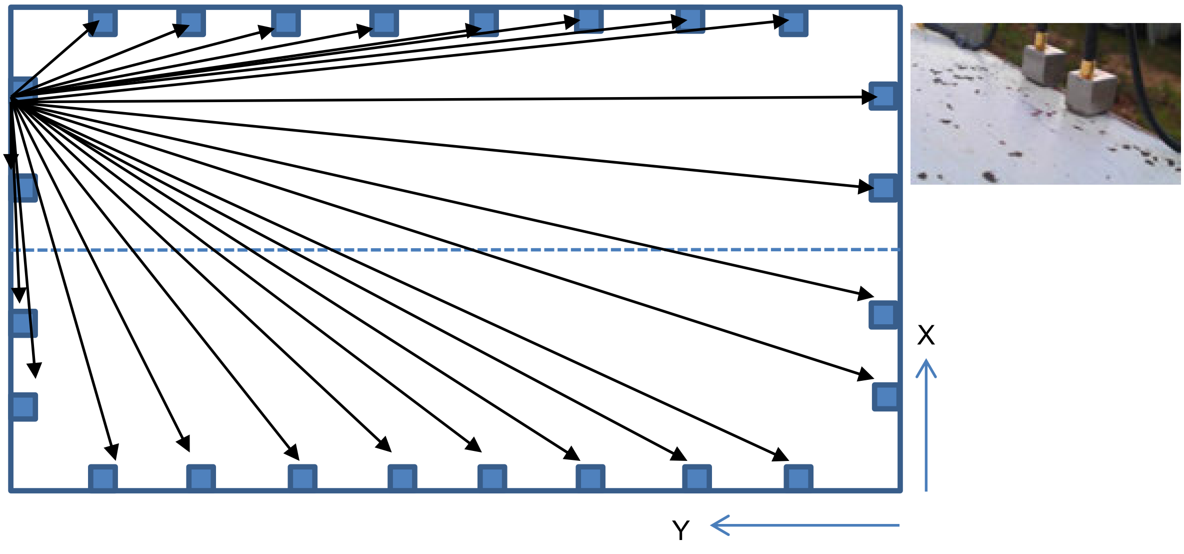

Figure 5. Arrangement of the transducers for the experiments. Transmission paths from one transducer are shown. Inset – one of the transducer pairs.

The approach was to gather data from the specimen over a period of time and to produce a set of baseline readings for a variety of temperatures. Readings were taken automatically every 6 hours over a two month period. These baseline data could then be compared with the data collected once a defect had been added. It was necessary to compare data sets taken at the same temperature, as variations in ultrasound velocity with temperature will give false indications if temperature is not compensated for.

Results

A defect 40mm in diameter and 10mm (1/2 plate thickness) deep was introduced into the specimen. This is shown in Figure 6.

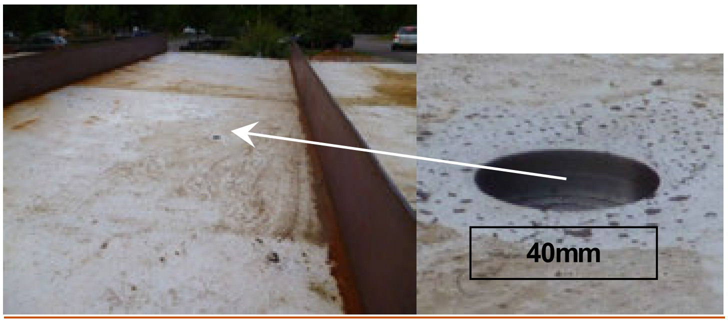

Figure 6. Defect introduced into the 12 x 6m plate

By transmitting on each of the transducers, shown in Figure 5, in turn and summing the results an ultrasonic image of the plate area could be produced. Figure 7 shows the results before and after the defect was added.

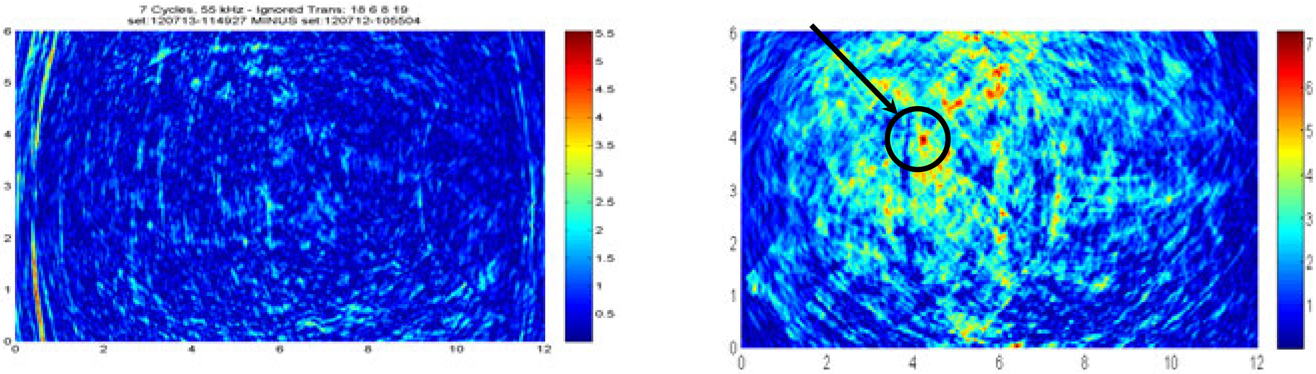

Figure 7 (left) baseline data and (right) after adding the 40mm diameter defect

This is an exceptional result. The area of the defect is only 0.002% of the area examined. To be able to detect it and to locate it accurately shows that this method is very powerful for the detection of small isolated defects in full scale ship structures. Figure 8 shows how this might be implemented using fully protected transducers.

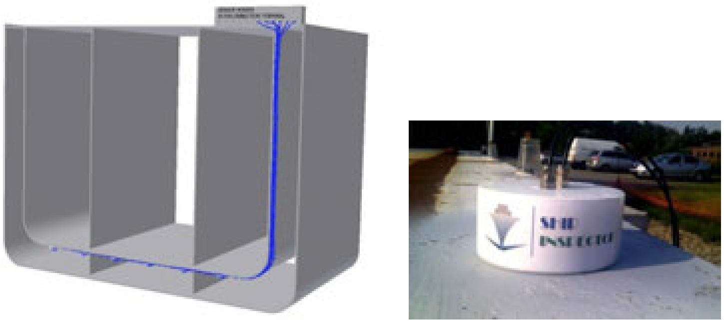

Figure 8. Schematic of the transducer installation for tank monitoring and the protected transducer.

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