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Development of Permanently Installed Transducers for Guided Wave Inspection

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SUMMARY

The use of guided waves for the inspection of pipelines has become increasingly routine in the petro-chemical industry over recent years. Originally developed as a tool for inspection for CUI it is increasingly being used for the inspection of any pipe particularly in areas where access is difficult. The ability of the technique to give quantitative/qualitative information about the pipe condition for areas remote from the transducer ring is an enormous advantage. However there are many occasions where the primary cost of the inspection is controlled by gaining access to the pipe. Two prime examples of this are sub-sea pipe and buried pipe. In these cases an attractive option is to gain access to the pipe for inspection and then leave a relatively cheap transduction system in place. A connector can be placed in a remote easy to access location so that periodic inspection can be carried out without needing to gain access to the pipe again.

DESIRABLE CHARACTERISTICS

There are many characteristics that are desirable in a permanently installed guided wave monitoring system of which the following can be considered a non-exhaustive list:

- Comparison of results to pre installation tests that can be made with a removable system.
- Operation over a wide frequency range.
- Determination of circumferential distribution of any material loss.
- Automatic recognition of test location and pipe ID.
- Automatic comparison of subsequent data collection with initial data to aid in the detection of changes.
- Compensation for variation in transducer coupling.
- Low profile transduction to allow installation in confined spaces (e.g. insider riser caissons).
- Cheap
- Choice of guided wave mode..

The challenge therefore was to produce a transduction system that would operate very much like the removable transducer rings that form the transduction part of the Wavemaker Pipe Screening System (WPSS). The recent introduction of a new electronics package for the WPSS allowed a number of benefits for a permanent system specifically an increase in the transducer cable length to over 100’ which allows much greater flexibility in the positioning of the transducer.

MECHANICAL DESIGN

Experience with using both torsional and longitudinal waves in testing of pipe work has indicated that the vast majority of pipe testing is either equally, or usually much better, accomplished using the torsional wave as opposed to longitudinal. There are a number of reasons for this.

- Torsional mode not affected by liquid inside pipe, no ghost echoes better range.
- Longitudinal mode generally requires 4 rows of transducers so the two similar longitudinal modes can be separated, torsional mode only requires 2 rows.
- Torsional mode exists from 0 kHz and is useable until the higher order torsional mode cut-off, so a large frequency range is useable. Longitudinal mode cannot always be used reliably at low frequency.

- Torsional mode has some sensitivity to narrow axially running defects whereas longitudinal mode is insensitive.

For these reasons the torsional transducer was considered more important and was developed first.

Torsional Mode Transducer

The design of transducers for testing heat exchanger tubes has meant that there was some experience with the design of much smaller transducers that are normally used for pipe testing. Generally, to produce a transducer that works at the low frequencies that are typically used for guided wave testing, a more massive transducer is used which tends to produce a bulky transducer. The tube testing transducers that have been produced suggested that reasonable performance could be achieved by using a transducer backing that reacted against the active element of the transducer with stiffness rather than mass. To this end transducers were produced that were simply PZT elements bonded to a band that could be wrapped around the pipe and glued in place. Initial transducers have used elements polarised such that they produce shear displacement at the pipe wall, and aligned such the combined effect of the elements is to produce a torsional wave that propagates along the pipe. In order to produce a directional system simply requires that two rows of transducers be applied to the pipe. The spacing between these rows will the dictate the frequency at which optimum control of direction and S/N is achieved.

The major problem encountered with this design of transducer compared to the removable system was the amount energy that would reverberate in the backing band. To overcome this a highly attenuating material has been used to absorb the reverberations. Initial tests on this type of transducer have shown that the output achieved is of the same order to that of the removable transducer. A slight reduction in performance has been seen in the near field where there is still some effect of reverberations.

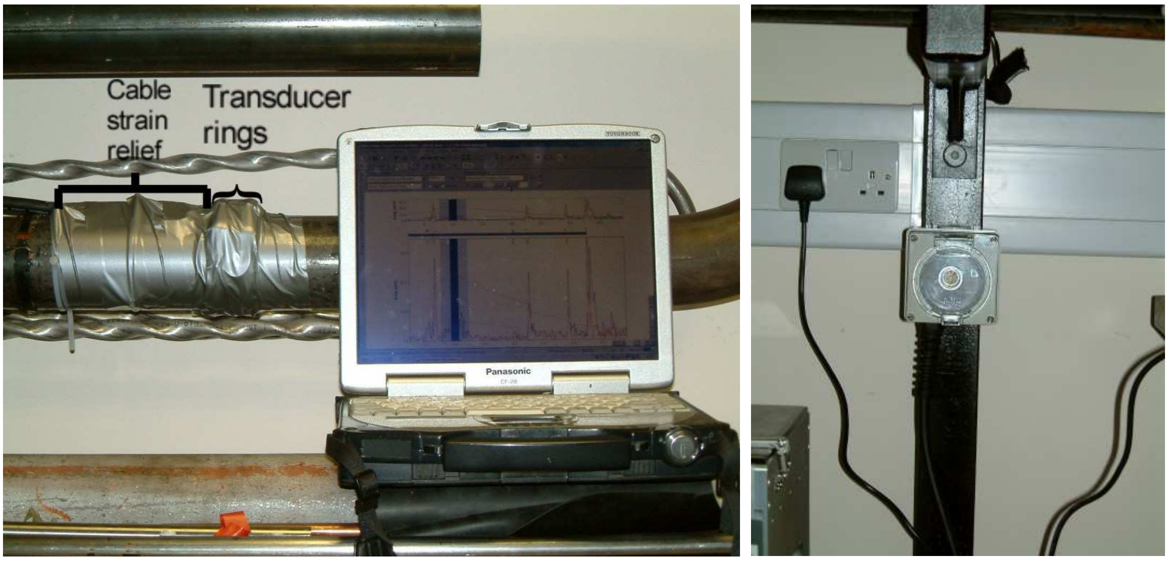

Figure 1 Permanently installed transducer on test pipe showing low profile of design and remote connection box.

Work is now concentrating on encapsulating the transducer and the wiring such that it would be possible to fit the transducer subsea. This could take one of two forms depending on the location that the transducer is required. The transducer can be assembled with a waterproof connector such that an R.O.V. can be used to make a connection and perform the test with the results relayed to the surface. Alternatively, for relatively shallow depth, the transducer can be fitted with leads long enough such the connection can be made above the surface, for example installed some way below the splash zone on a riser, with the connection point being on the platform. This would allow the critical splash zone area to be monitored without the need for divers in the water.

Longitudinal Mode Transducer

Some of the earliest experience with guided waves in pipes had been using strain gauges bonded directly to the pipe. Using an array of PZT elements polarised such that they expand when subjected to charge can easily be used to produce a longitudinal guided wave mode. The advantage of this type of element is that it produces strain directly in the pipe wall. Another advantage of using this type of element is that PZT polarised in this manner is cheaper to produce so the individual element cost is lower, however this almost always off set by the need to have four rows of transducers so that unwanted longitudinal mode can be suppressed. Assembly of this style of transducer is also easier.

DEPLOYMENT

The preferred method of deployment of these transducers is as part of a new build, where the transducers can be applied to the pipe prior to any corrosion protection system. This allows the transducer to be in perfect contact with the metal of the pipe, and can also allow the corrosion protection being applied to the pipe to be continuos thus avoiding problems of the transducer increasing the corrosion potential of the pipe.

However it is likely in most circumstances that these transducers will be retrofitted to pipes. In this case it is intended to use a protective polypropylene potting around the transducer once it has been attached to the pipe. This will not only act as waterproof coating on the transducer but will also act as an attenuating material that will adsorb energy trapped in the transducer backing.

The cable that is used will vary depending on application, and the level of protection that will be required but it is anticipated that the cable will be armoured to give both electrical and mechanical screening. Also the level of protection required for the connection box is likely to vary from application to application.

TOSIONAL TRANSDUCER PERFORMANCE

The following two figures show the results obtained from a fixed transducer ring and the permanent torsional transducer.

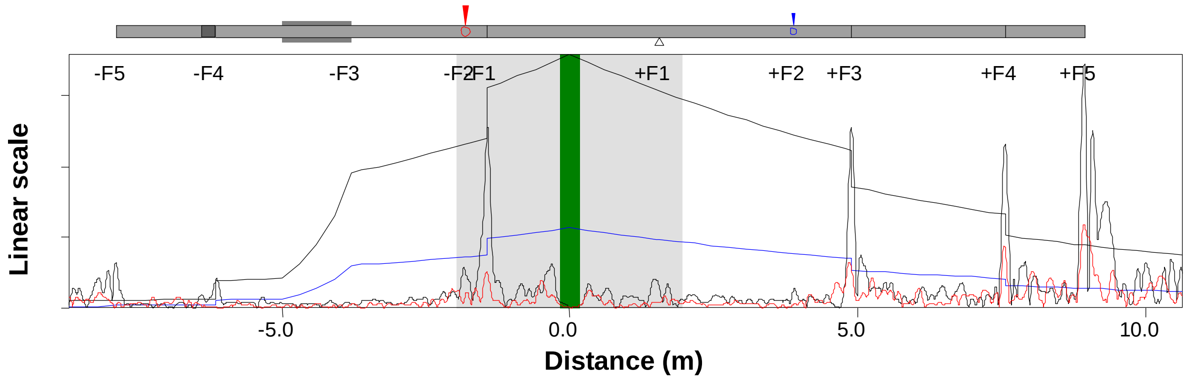

Figure 2 Result from test loop using removable transducer.

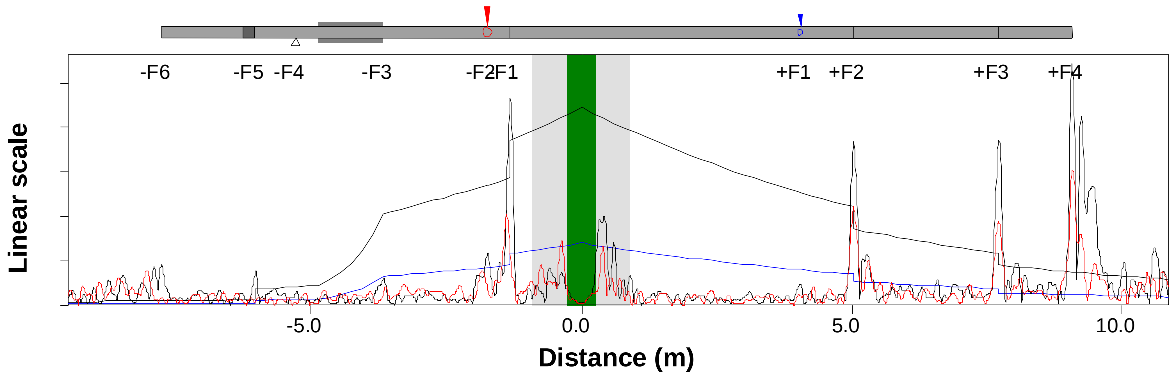

Figure 3 Result from test loop using permanent torsional transducer.

The two results show that the performance of the permanent transducer is very similar to that of the removable transducer. There is a slight reduction in the signal to noise in the near zone of the transducer due to the energy in the backing, but it is expected that an increase in the thickness of the attenuating material used on the backing should help reduce this further. It can also be seen that the absolute signal amplitude is higher which is likely to be a significant benefit for the inspection of buried pipe where absolute signal amplitudes are very low (although it should be noted that signal to noise is the more important measure in terms of minimum detectable defect size).

CONCLUSIONS

It has been shown that a relatively simple transducer can be constructed that when glued to a pipe can give results that are comparable to the more substantial transducer that is usually used for guided wave inspection. Although the cost of this style of transducer is not insignificant it represents a substantial saving when compared to the cost and time saving that it allows for repeat inspections on hard to access pipes. It is also important that the features that are available to the operator of the removable transducer system are still available when using a permanent system. Amongst the most important are: ability to detect circumferential distribution of wall loss; calibration of system to ensure symmetric output and operation over a wide frequency band. All of these features are regularly used to help operators make accurate defect calls. The accuracy of calls, and the reduction of false calls become more important the less accessible the pipe is.