Achieving greater efficiency in NDT inspections

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Introduction

The introduction of new technologies and techniques is revolutionising non-destructive testing, and allowing faster, more cost-effective inspections. As inspection companies achieve ever greater efficiencies, the benefits are felt by industry as a whole – lower construction costs, for example, and faster timescales.

A current project being carried out by the Australian inspection company C.W. Pope illustrates this concept. The company, which is testing a new ammonia storage tank in northern Australia (Figure 1), has so far reported savings of around £75,000 on inspection costs by using semi-automated ultrasonic techniques in place of radiography.

However, the real savings lie in the faster construction process which the technology allows. In this case, it is estimated that up to 60 days could be saved in the project as a result.

Radiography versus ultrasonics

The Australian project has set a precedent in using ultrasonics to carry out an inspection of this type. Of the two major methods of inspecting welds volumetrically, radiography has often had the edge in the past because it was able to provide a permanent record of the inspection on film. With ultrasonics, however, it was left to the judgement of the technician carrying out the inspection as to whether there was a defect.

How times have changed! Now, the advent of faster, more powerful computers means that the whole process can be stored on disk, while advanced software programmes allow better interpretation of data. Replacing radiography with ultrasound not only allows faster, more economical inspections but also eliminates the health and safety risks associated with radiography. In practical terms that means there is no need to evacuate the site for inspection purposes – construction work can continue, round the clock if necessary, thus dramatically reducing construction times.

How do the two techniques compare on accuracy? Our view is that the results from automated ultrasonics can be comparable with, if not superior to, radiography. As yet, no exhaustive research has been carried out to...
compare the two. In view of its importance, this is an issue which the industry badly needs to address.

One of the most authoritative studies in recent years was that by RTD Quality Services on behalf of the American Gas Association’s Pipeline Research Committee. In their report, RTD point out that ultrasonic methods, contrary to radiography, can be applied with engineering critical assessment (ECA) acceptance criteria – but that the main difficulty is in providing a reliable inspection of the root region.

Reiterating what has been one of the recurring arguments of radiography fans, they say: “On the one hand, defects could be overlooked because they sometimes cannot be separated from root geometry signals. Conversely, geometry echoes (caused by, for example, hi-lo)\[1\] can erroneously be interpreted as defects, giving rise to false calls.”

Though the study primarily focuses on the inspection of the root region of pipelines, it provides valuable information. RTD tested the same lengths of pipeline, employing both mechanised ultrasonic techniques with computer-aided features and superior radiography techniques (D4p Pb film).

They conclude: “From a detection point of view, and also based on false call rates, it appears that the inspection quality obtained with a state of the art system for mechanised pipeline girth weld inspection can be compared to that of a good radiographic technique. Especially in the root region, inspection quality of (improved) mechanised UT sometimes appears to be even considerably higher. False call rates are in the same order of magnitude as those of radiography.”

Studies like this are helping to dispel the old arguments. Meanwhile, users are increasingly employing ultrasonics as the more modern, cost-effective choice.

**Automated and semi-automated scanners**

The effectiveness of ultrasonics has been assisted by the availability of automated or semi-automated systems. In my opinion, this is largely due to the transfer of technology from the nuclear industry, where such systems were pioneered.

Companies like Phoenix, which have long specialised in the design and manufacture of automated systems for the nuclear power generation field, are now able to use the expertise to produce affordable mechanised scanners for the wider market. Phoenix has also followed a policy of producing a wide range of standard, adaptable products which means the majority of users can find an off-the-shelf device to suit their needs.

In the case of the Australian project, however, Phoenix worked with C.W. Pope to design and manufacture a system to match their needs exactly. The primary requirement was for a light portable scanner that could be assembled with the minimum of fuss to avoid time-wasting on site. It also had to withstand the rugged conditions in northern Australia, where temperatures can reach up to 38°C, with very high humidity.

Known as the Magman, the scanner was designed for use without tools – all the operator has to do is simply slacken the thumbscrews, insert the probes and the system is up and running. The robust rectangular frame holds six probes ± although it can accommodate more – all of which can be positioned from 20mm to 250mm apart. All four wheels are independently sprung, to ensure that contact is maintained on rough surfaces, and probes are fully gimbaled and sprung to maintain signals (Figure 2).

As the operator pushes it along the length of the weld, a weld guide and magnetic wheel ensure accurate tracking and a positional encoder determines true linear position. The Magman can operate in any orientation from flat plate through to 150mm O/D pipe, and can be driven axially along the underside of...
pipes. It is very much a field vehicle, requiring little maintenance and, once the current project is completed, should prove a valuable tool which can be easily adapted for use on many other inspections.

**Time of flight diffraction**

Further savings have been achieved by the use of TOFD as an inspection method, in conjunction with creeping wave, for the detection of near surface flaws.

Experts in the industry are still divided about this relatively new search technique and this is surely another area where some definitive research is needed to help achieve a greater consensus of opinion. TOFD was devised by Dr Maurice Silk at AEA’s Harwell site in the early 1970s, in response to the nuclear industry’s need for a more accurate method of detecting and sizing flaws in critical plant components already in operation.

For many years it was employed only for sizing defects. Its new-found popularity as a search tool – albeit often as a back-up running alongside more conventional methods such as pulse echo – means it is currently the fastest growing ultrasonics technique. As in the case of automated scanners, this trend has been aided no doubt by the advent of faster, more powerful computers.

TOFD is indeed a very fast and efficient way to cover the whole weld volume with very few probes. Its supporters point to its ability to detect the presence of both fabrication and service-induced defects, particularly those affecting integrity owing to their through wall orientation, while simultaneously providing the data necessary for accurate assessment of their size.

With TOFD, a single line scan of a pair of angle compression wave probes held at fixed separation can provide full volumetric coverage of both weld/HAZ and generate an immediate scale image of through wall condition with defects shown in true location and size (Figure 3). The wide beam used defines the test surface by generating a lateral wave and the inner surface by reflections off the material backwall. Any anomalies lying between these two surfaces are highlighted by signals diffracted and reflected off their extremities. The lateral location and length of these discontinuities are reported as a function of encoded scan position.

Critics of TOFD cite difficulties in interpretation as one of the technique’s limitations – or fear that it may miss critical defects. By contrast, TOFD fans argue that, being based purely on time-lapse measurement of diffracted (and reflected) responses from any defects within and the geometry of the material under test, the technique effectively eliminates the main deficiency of conventional pulse echo examination – reliance on variable amplitude response as a basis for detection and sizing. They claim TOFD is actually simpler and more reliable. However, because of its resolving power, and the composite graphical fashion in which the data are presented, it does tend to “show everything”, which can be disconcerting to those unfamiliar with the principles.

The resolving power of TOFD is such that material structure itself can often be visualised. The typical D scan image is a through wall sectional elevation in the direction of scanning. It is made up of all the signal responses captured by the beam transmitted between discreet transmit and receive transducers. As such, it is an image of the entire volume of material insonified by this beam and anything in its path is likely to be observed. It follows that “dirty” weld and coarse grain material will generate a lot of responses and, because all these are superimposed on a 2D of a 3D object, the resultant picture is likely to be confusing. But far from being detrimental, TOFD supporters believe this is often an advantage. If the welding or parent material is so poor there is obviously a problem that has been highlighted and steps...
can be taken to assess further its nature and extent.

They point out that, where non-integrity affecting defects occur, such as minor fabrication flaws like slag and porosity, these are imaged in a way that graphically represents their nature, as small, isolated inclusions against a backdrop of “clean” material. Where more significant defects such as cracks and LOF are present, TOFD will show these in their true scale size and position – almost as if the metal had been sliced and a “macro” produced. Even microscopic flaws, such as stress and chemically induced structural damage, can be seen, and minute embodied flaws, such as those associated with cladding interface cracking, can be differentiated from parent metal and bonded substrate.

One of the limitations of TOFD is that the lateral wave impedes near surface resolution (3mm). Therefore, other techniques, such as creeping wave, must be used to ensure full coverage of this area.

The TOFD technique has been subject to a number of notable trials including the publicly scrutinised Sizewell B Defect Detection Trials, which confirmed that it offered the best sizing accuracy and added that it “has been compared to pulse-echo and radiographic techniques for detection and length sizing performance. On all but the thinnest plate, TOFD performed at a similar level to these systems” and “has now been demonstrated on a thick section . . . to meet the requirements of ASME (Code Case 2235).”

AEA, which remains a keen supporter, says: “TOFD has been shown to offer higher probability of detection (POD), lower false call rates (FCRs) and now offers a real alternative to radiography during construction.” Certainly in terms of speed and cost-effectiveness, TOFD’s performance is impressive.

In the case of the Australian project, TOFD was used with creeping wave for inspection purposes. The decision was taken with the full
agreement of C.W. Pope’s client, who had been introduced to the technique at seminars and was fully aware of the benefits it would bring to production schedules.

**The results**

Both the inspection company and its client have been delighted with the results. The Magman scanner has proved highly popular with the team. C.W. Pope’s spokesman Steve Prince, who trialled the equipment himself, notes: “35m of weld on 32mm thick plate was tested in less than four hours with plenty of interruptions. I will have no trouble improving this productivity rate . . . It would take a radiography crew 14 hours on night shift to test the same weld”.

The £75,000 saving on inspection costs will be considerably more when the process is complete. Instead of the site being evacuated for radiography, the system has allowed testing behind the welders – in fact, while the welds are still warm. With no interruptions to construction work, the project could be completed up to two months ahead of schedule.

With faster, cheaper computers and scanners now available, mechanised ultrasonics is increasingly becoming the preferred method of NDT in situations where previously radiography and manual ultrasonics would have been used.

**Note**

1 Hi-lo is a commonly used term in the industry. Where two pieces of metal are welded together a mismatch between the two means that one piece is slightly higher than the other. Depending on the specification some degree of mismatch is acceptable, and indeed is inevitable.