Supporting Industry

Industrial Member companies benefit from the technical support offered by TWI across all areas of NDT, structural integrity, materials engineering and joining technology. This enables our customers to:

- reduce costs/increase profitability
- improve safety, quality and availability
- extend useful service life
- increase competitive advantage
- develop and innovate processes
- improve material assessment and selection

Examples of TWI's NDT projects and services

Technical audits, etc.

- Writing and reviewing procedures
- Witnessing inspections
- NDT Level 3 services

Automation:

- Robotic inspection of aircraft structures
- Vehicle-mounted rail inspection
- Robotic ACFM for storage tanks
- Automated inspection of GRP air turbine blades

Phased Array Systems:

- Probe specification
- Application to critical components in aerospace, vehicles, oil & gas and rail transport infrastructure

Long Range Guided Wave:

- Phased array development
- Wave propagation and defect detection modelling

Friction Stir Welding:

- Detection of fabrication flaws
- Process parameter monitoring for control of joint line remnants
- Complex shapes

Novel Methods:

- Low frequency modal analysis
- Computed / digital radiography and tomography
- Thermography

Corrosion:

- Detection and Mapping
- Statistical Modelling
- Probabilistic Analysis

Site Inspection Services:

- Manual UT, eddy current, ACPD & ACFM
- TOFD & phased array UT weld inspection
- Automated pulse echo zonal inspection of pipeline girth welds
- Long-Range Ultrasonic Testing
- Automated Corrosion Mapping

Materials:

- Metals
- Plastics
- Composites
- Ceramics
- Adhesive Bonds

Structural integrity:

- Inspection Validation and Qualification
- Condition Monitoring

Microtechnology:

- In-line quality control
- Integration of multiple techniques
- Micro-focus X-ray

Manufacturing Support:

- Production line detection of porosity in magnesium castings
- Control of PCB quality
- UT inspection of pressure vessels to ASME codes

Training and Education:

- NDT training and certification to international standards
- Technology overviews and application specific courses, tailored to your requirements

Please contact TWI if you would like to know more about the services outlined in this brochure.

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TWI Non-Destructive Testing Services

TWI
WORLD CENTRE FOR MATERIALS JOINING TECHNOLOGY

TWI's Specialised Non-Destructive Testing Services

Over many years TWI has been developing a powerful group to conduct research and provide consultancy and laboratory and site services in the field of non-destructive testing (NDT). There are now over 50 scientists and technicians working at TWI in this area. In 2003, TWI was selected by the Welsh Development Agency to establish a centre of excellence in NDT technology at Port Talbot in South Wales. TWI's NDT services are now provided from this centre and from TWI's headquarters at Abington, near Cambridge.

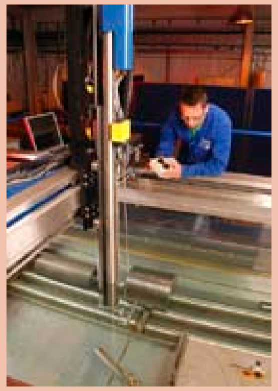
Also based in Port Talbot and managed by TWI is the Non-destructive Testing (NDT) Validation Centre. This was officially opened in March 2006. The Centre is run in collaboration with Swansea Institute of Higher Education and Swansea University and is an independent organisation, which assesses the accuracy and consistency of NDT methods used in manufacturing and construction and in service. It addresses the need to verify and improve the accuracy of inspection techniques and the reliability of flaw detection to increase the confidence of manufacturers, regulators and users alike.

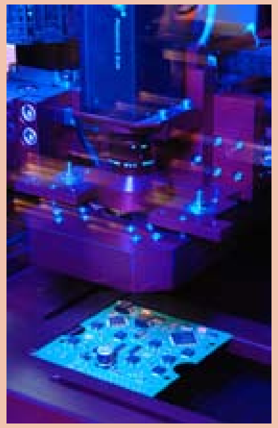
TWI is able to deploy a wide range of technologies to solve the NDT problems of Industrial Member companies. To support these technologies it owns and operates a range of state-of-the-art systems. They can be operated on site anywhere in the world or in TWI's laboratories.

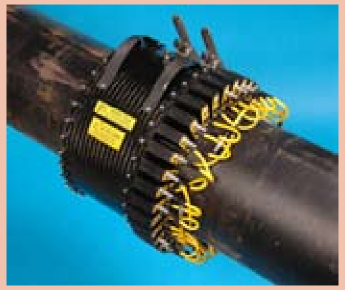
The technologies and the supporting systems available at TWI are:

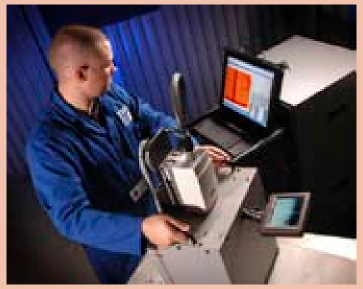
- Computerised ultrasonic flaw detection, location and sizing:
  - Phased array systems
    - Olympus NDT Tomoscan Focus
    - Olympus NDT Omniscan MX PA
    - Peak NDT Micropulse 5PA
    - Harfang X-32 (8 units)
  - Advanced multi-channel computerised flaw detection systems
    - Force P-Scan System 4+
    - Zetec Tomoscan III
- Ultrasonic Time of Flight Diffraction (TOFD) for critical flaw sizing
  - Force P-Scan System 4+, Sonotron Isonic 2005 and Inspection Solutions USB Sectorscan
- Ultrasonic corrosion mapping:
  - Force P-Scan System 4+ used in the thickness scan (T-Scan) mode
  - Inspection Solutions USB Sectorscan
- Ultrasonic bond testing
  - Bondmaster 1000
- Ultrasonic flaw imaging in the C-Scan mode
  - NDT Solutions RapidScan 2 system
  - Immersion testing using Ultrasonic Sciences' 6 axis probe manipulation gantry
- Rapid Automated Ultrasonic Testing (AUT) for zonal inspection of pipeline girth welds
  - RD Tech Pipewizard
- Long Range Ultrasonics (LRUT) for pipe and pipeline inspection
  - Plant Integrity Limited's *Teletest*® and *Teletest Focus*™ systems
- Ultrasonic modelling
  - Abaqus Finite Element analysis software
  - CIVA / Acoustic Ideas' Continuum software
- Acoustic emission (AE)
  - Physical Acoustics 2-channel AE system
- ACFM for surface crack detection and sizing
  - Three ACFM Amigo Units
- Eddy current testing for surface crack detection and sizing
  - RD Tech MS 5800-ER computerised system (2 units)
  - TMT eddyMax 4U computerised system
  - Phasec 2D portable dual frequency
- Optical Imaging and Digital Image Processing mainly used for inspecting electronic components and PCBs
  - Machine Vision Products (MVP) AOI system
- Laser Shearography
  - Laser Optical Engineering Ltd's Strain Mapper
- Thermography
  - Fluke Ti30 hand-held thermal imaging camera
  - LOT Oriel / Thermal Wave Imaging Inc system
- Digital Radiography / Computed Radiographic Tomography
  - X-Tek 450 keV
  - X-Tek 75 keV portable
- Micro-focus X-ray
  - X-Tek 225 keV Microfocus

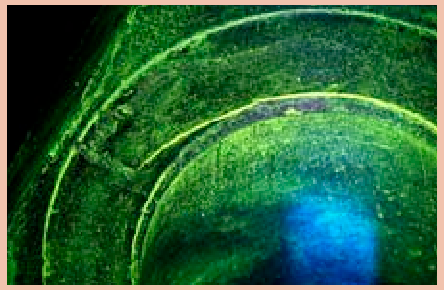
Experienced and fully qualified PCN/CSWIP technicians operate all these systems. Apart from Teletest®, TWI has no direct interest in the supply of any of these systems. It can therefore offer totally unbiased advice on the appropriate systems to be used for any particular industrial application.

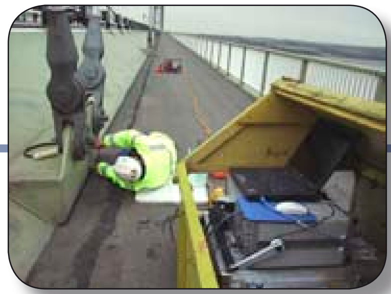




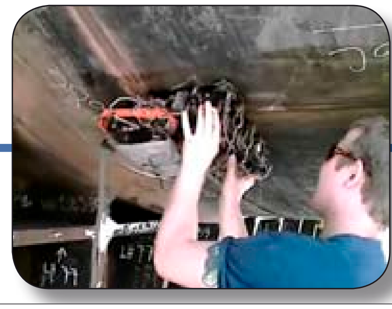








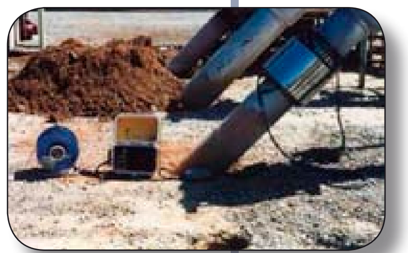
Phased array ultrasonic inspection of a longitudinal weld on Humber suspension bridge



Saudi Arabia - TOFD inspection of pressure vessel longitudinal seam using magnetic crawler

Teletest Focus™ in use at a US oil terminal

Florida - Teletest® inspection of buried pipeline and corrosion located on this job



PipeWIZARD® inspection of pipeline girth welds.

Photograph courtesy of Olympus NDT

Eddy current testing to detect fatigue cracks in aircraft wing flap mechanism

TWI's NDT Site Services

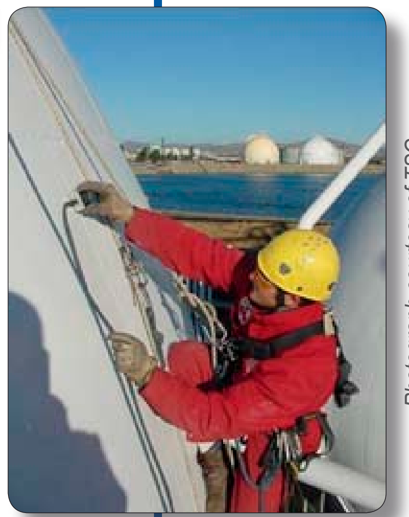
TWI has an unrivalled selection of non-destructive testing equipment available for work on site. The equipment is operated by highly qualified Level 2 or 3 engineers. Should they require assistance, they can call on the support of the 50 strong team of NDT scientists and technicians based in Cambridge and Port Talbot in the United Kingdom. Furthermore, TWI's structural integrity, materials engineering and corrosion engineering experts are available to assist in interpretation and evaluation of any data gathered.

TWI's site NDT staff travel extensively and TWI has carried out site NDT work as far afield as Alaska, Indonesia, Venezuela, Kazakhstan, Saudi Arabia, and the Gulf of Mexico, etc. Site teams can be mobilised rapidly and the staff are fully accustomed to site working conditions – offshore, arctic, tropical, etc.

The techniques that TWI applies on site are: -

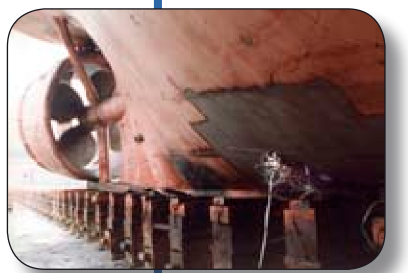
- Manual Ultrasonic Testing (often used as follow up to mechanised techniques)
- Automated UT of pipeline girth welds
- Long range UT*
- Phased array UT
- Time of flight diffraction UT (TOFD)
- TOFD at high temperatures (up to 250°C)
- Alternating Current Field Measurement (ACFM)
- Eddy current

* Service provided by TWI's subsidiary, Plant Integrity Ltd (Pi), using the Teletest Focus™, LRUT system



ACFM inspection of gas storage sphere welds

Photograph courtesy of TSC



P-scan crawler mounted on ship's hull to inspect for internal corrosion

Louisiana - Teletest® inspection of 48" diameter bayou crossing

TOFD inspection of offshore riser weld

Teletest® inspection of buried pipeline

Phased array inspection of polyethylene gas pipe

Phased array inspection of splice welds on Mardle Viaduct

Brazil - phased array inspection of FPSO turret weld for Petrobras

NDT Services from TWI

Acoustic Emission

Description

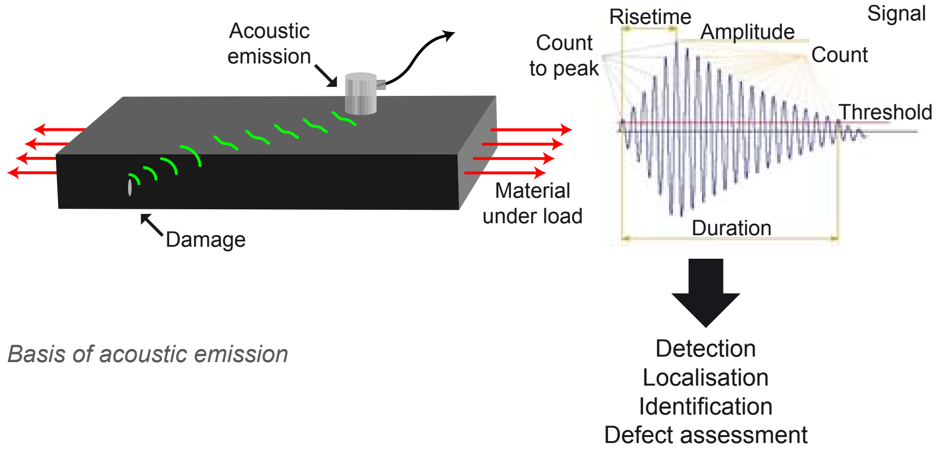
When a load is applied to a structure, it deforms elastically. Associated with this deformation are changes in the structure's stress distribution and the storage of elastic strain energy. As the load increases further, some permanent microscopic deformation may occur, which is accompanied by a release of strain energy, partly in the form of a propagating elastic wave termed 'Acoustic Emission' (AE). If these emissions are above a certain threshold level they can be detected and converted to voltage signals by sensitive piezoelectric transducers mounted on the structure's surface.

A typical AE system consists of data acquisition, amplification, processing and analysis. Various parameters are used in AE to characterise the source, including: ring down count, cumulative duration, peak amplitude, rise-time, energy, frequency and RMS (Root Mean Square) voltage.

AE can detect cracking, corrosion, friction, mechanical impact and leaks. In particular, it is sufficiently sensitive to enable cracks extending by as little as a few hundred square micrometers to be detected. It can be used to monitor metallic structures, composite materials and concrete.

It is used for:

- Pressure equipment: to monitor flaws, corrosion, and leakage in pressure vessels, LPG, tanks, piping systems, steam generators;
- Aircraft and aerospace: airframe structures, wings, bulkheads, fuel tanks, etc.;
- Oil / chemical industry: storage tanks, reactor vessels, offshore and onshore platforms, drill pipe, pipeline;
- Marine: corrosion, composite shell, engine and power plant;
- Civil engineering: bridges, dams, suspension cable bridges.



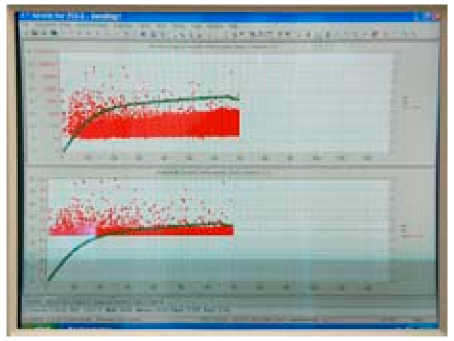
Basis of acoustic emission

An important aspect of AE is signal processing. Genuine stress-wave emissions originating from within the material must be separated from external signals, such as environmental noise (e.g. rain, wind), mechanical noise, electrical noise, etc. This is achieved by electronic filtering. The frequency of the stress waves emitted is normally in the range 30 kHz to 1 MHz. Triangulation and other techniques can give positional information and localise the sources of the emissions.

Advantages of AE are:

- Real time monitoring in service structures
- High sensitivity
- Defect localisation
- Monitoring of non accessible zones

TWI has a basic 2-channel AE system supplied by Physical Acoustics, which is mainly used in laboratory investigations.



Physical Acoustics software output showing 'events' against load on a component. The upper display shows event energy and the lower event amplitude.

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NDT Services from TWI

Alternating Current Field Measurement (ACFM)

Description

ACFM is used for detecting and sizing surface breaking flaws. Technical Software Consultants (TSC) developed ACFM as an extension of the successful Alternating Current Potential Drop (ACPD) technique. It was initially conceived for use under water to detect flaws in offshore structures and to overcome the fact that ACPD was unsuitable for such applications because of the need for good electrical contact between probes and the structure's surface. Now, however, ACFM is also applied to structures both in and out of the water. (It has the advantage over some other techniques that the structure requires minimal cleaning and that it can be applied over paint and other coatings up to several millimetres in thickness.)

ACFM is an electromagnetic technique. A sensor probe is placed on the surface to be inspected and an alternating current is induced into the surface. When no defects are present the alternating current produces a uniform magnetic field above the surface. Any defect present will perturb the current forcing it to flow around and underneath the defect; this causes the magnetic field to become non-uniform and sensors in the ACFM probe measure these field variations.

Two components of this magnetic field are measured - one provides information about the depth or aspect ratio of the defect(s), and the other shows the positions of the defects' ends. The two signals are used to confirm the presence of a defect and, together with a sizing algorithm, measure its length and depth.

The advantages of ACFM are that it:

- Works equally well on parent material or welds, ferritic or non-ferritic metals.
- Can be used on hot surfaces, underwater, or in irradiated environments.
- Provides both depth and length information. Accurate sizing of defects up to 25mm (1") in depth.

TWI owns the state-of-the-art Amigo ACFM system supplied by TSC.

Selected clients and applications

ACFM is particularly suited to the detection and sizing of fatigue cracks at the toes of welds, including all butt, fillet, node and nozzle welds. TWI has applied its AMIGO system in this role for inspection of fillet welds under the orthotropic decks of several highway bridges. These have a paint coating so that ACFM was particularly suitable. In some cases inspections are made to a routine schedule to determine whether crack growth is occurring. TWI has also used ACFM to inspect fillet welds in Mobile Offshore Drilling Units (MODUs) to detect any possible original fabrication hydrogen cracking present at weld toes. It has also been successfully deployed in the laboratory in a joint industry project to detect stress corrosion cracking in duplex stainless steel pipe welds.

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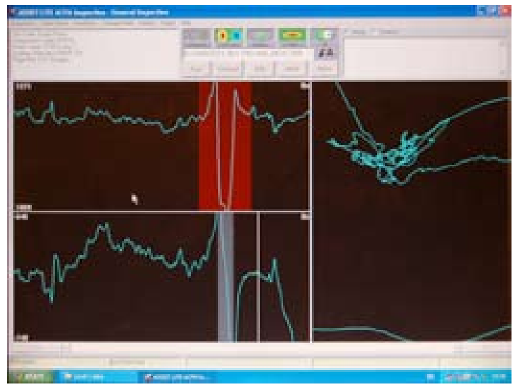
ACFM probe and AMIGO instrument in operation



ACFM screen output from Amigo unit, showing large flaw in region identified in red

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NDT Services from TWI

Automated Optical Inspection (AOI)

Description

Automated Optical Inspection (AOI) uses a combination of optical imaging and digital image processing for the inspection of printed circuit boards (PCBs) in the electronics industry.

The technique employs a Golden Image of a ‘good’ PCB from which the active image of the PCB being inspected is subtracted. Any resulting difference can be used to pinpoint potential defects and for automatic defect recognition. TWI is investigating this technology using Machine Vision Products (MVP’s) Gem Tabletop system and using TWI’s own bespoke hardware and software algorithms. The photograph below shows a PCB being inspected with the optical imaging camera.

There are three critical stages in PCB manufacture; solder paste printing, component placement and reflow oven. AOI can be used after each stage. After printing, AOI can detect whether the stencil was correctly aligned. Incorrectly placed or missing components can be detected after the board has been populated. The final inspection after the PCB has been through the reflow oven can show up excess or insufficient solder and can detect if any component has ‘migrated’ during the reflow process.

The residual image left after subtracting the golden image from the image of the target PCB will be black except for areas of difference. These are therefore potentially defective. The four images at the top of the page illustrate the technique. The image labelled ‘d’ shows the residual image overlaid on the golden image. Suspect areas or components are indicated in green.

AOI is not restricted to PCB inspection. It can be used for surface inspection of any material and can be used to replace other forms of visual inspection.

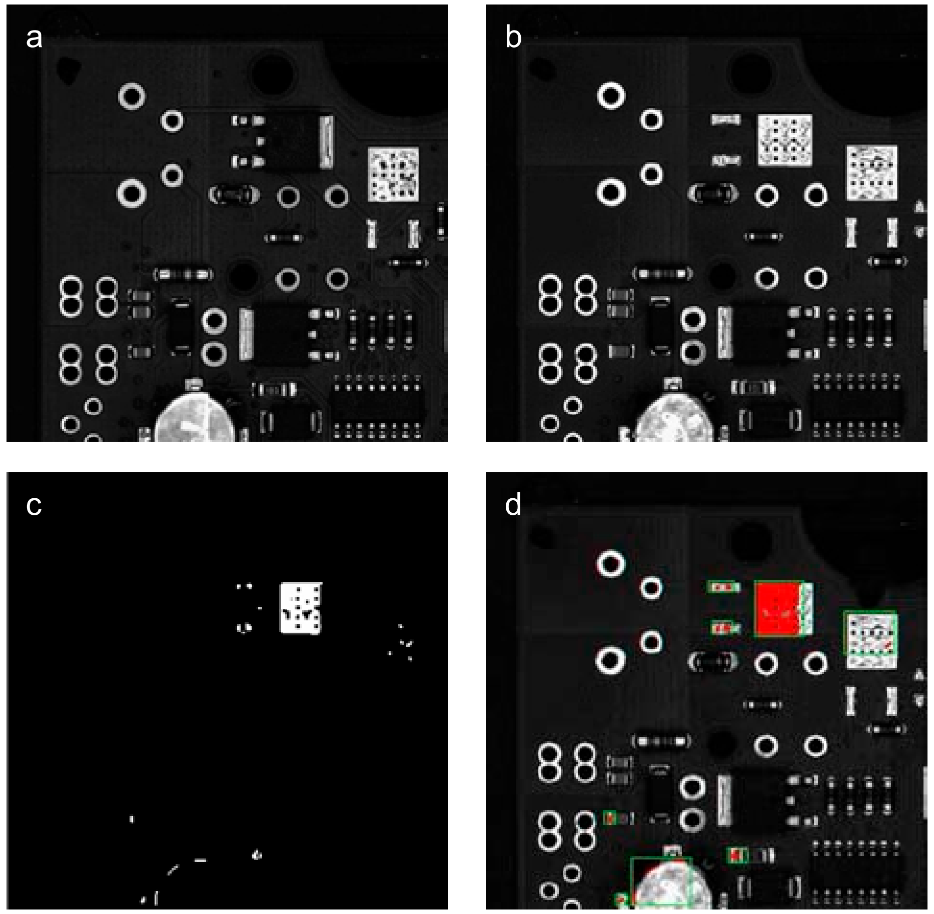

Illustration of the Automated Optical Inspection technique, showing (a) the Golden Image, (b) the target image, (c) the residual image (target image subtracted from the Golden Image, and (d) the residual image overlaid on the Golden Image showing defective areas highlighted in green.

A PCB under the optical imaging camera

Applications

TWI is currently investigating the use of AOI as one technique in an integrated system for PCB inspection. Other techniques for potential inclusion in the overall inspection system are micro-focus x-ray, acoustic methods and thermal / infrared imaging. This work is being undertaken in the Microscan collaborative project partly funded by the European Commission.

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NDT Services from TWI

Automated Ultrasonic Testing (AUT) of Pipeline Girth Welds

Description

In automated ultrasonic testing (AUT) of pipeline girth welds a number of separate fixed angle probes or a pair of phased array probes are mounted on a band strapped around the pipe, positioned each side of the weld and driven around the pipe's circumference. As the probes travel around the pipe, ultrasonic data are collected from the weld and the software calculates flaw sizes and positions for display. Very fast circumferential speeds (~100mm/s) are called for, since, to keep pace with construction, it is necessary to complete a weld inspection every 2-4 minutes. AUT is replacing radiography for pipeline girth weld inspections worldwide. The advantages of conventional AUT over radiography are:

- No radiation hazard.
- Better process control of welding through rapid feedback, giving lower reject rates.
- Improved defect evaluation by using Engineering Critical Assessment (ECA) criteria.
- Rapid and reliable data interpretation from specialised output display.

TWI's AUT system is the PipeWIZARD® supplied by Olympus NDT. This has the further advantage over conventional AUT systems that it utilises phased arrays. These offer major advantages over conventional AUT in constant geometry components such as pipeline girth welds.

- Smaller probe pans, reducing the length of pipe coating that has to be cut back.
- One PipeWIZARD can scan pipes ranging in diameter from 2 in. to 56 in.
- The standard PipeWIZARD can scan pipe walls from 6 mm to 50 mm.
- Multiple zones for better detection and vertical sizing.

TWI's PipeWIZARD crawler mounted on a pipe for laboratory trials

PipeWIZARD in the field (courtesy of Olympus NDT)

- Any weld profile, pipe diameter, or wall thickness can be accommodated by recalling the appropriate previously saved setup files.
- Arrays can be programmed to check the coupling automatically using the back wall echo.

PipeWIZARD computer screen

In the PipeWIZARD computer screen shown, the vertical plots are the signals associated with specific zones of the weld (cap, body and root) on the upstream and downstream sides of the weld. Each zone is approximately 2mm deep and is scanned by selecting an appropriate focal law that controls the phasing of the array. The screen display essentially 'opens out' the weld from the root. Flaw lengths are estimated from circumferential position markers and depths from the number of zones affected. The red zones are above a predefined threshold. The central grey area is a Time of Flight Diffraction (TOFD) plot. (See separate sheet for description of TOFD.)

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NDT Services from TWI

Computerised Pulse Echo Ultrasonic Flaw Detection, Location and Sizing

Description

Phased array ultrasonic systems utilize multi-element probes, which are individually excited under computer control. By exciting each piezo-composite element in a controlled manner a focused beam of ultrasound can be generated. This beam can be steered by use of the software. Linear and sectorial scans are possible, and, in conjunction with probe scanners, 2 and 3 dimensional views can be generated showing the sizes and locations of any flaws detected.

TWI owns a range of phased array systems. They are as follows:

- Laboratory / bench units
    - Olympus NDT's Tomoscan Focus. A 32 channel system.
    - Zetec Tomoscan III. A flexible and powerful system capable of handling up to 128 channels of phased array ultrasound channels
    - Peak NDT's Micropulse 5 PA system. This is an advanced unit developed for the nuclear industry with 128 channels.
- Portable units
    - Olympus NDT's Omniscan MX PA. A robust 16 channel unit. (TWI owns 5 of these systems).
    - Harfang Microtechniques X-32. TWI owns 8 of these units. They are robust and extremely well adapted to site use.

Phased array probe on a calibration block

Harfang flaw detector in use for weld inspection

For non phased array inspections, TWI employs the P-Scan from Force Technology. Utilising both focused and unfocused conventional probes, this is an extremely robust system that is ideally suited to weld flaw detection and sizing. It can be linked to a wide range of mechanised scanners, which manipulate the ultrasonic transducer(s).

Alternatively a single probe with mechanical linkage to record its position and orientation can be manipulated manually, thereby permitting a fully recorded, code compatible, manual UT inspection. The electronic system records the position and orientation of the transducers and uses these data and the ultrasound reflections to simultaneously produce through thickness and plan view projections showing the positions and sizes of any flaws. The latest P-Scan system 4+ owned by TWI has the following capabilities:

- P-scan **weld inspection** producing through thickness and plan view projection images.
- T-scan **corrosion mapping** displays variations in thickness as a coloured plan view of the test piece, allowing detection of isolated corrosion pits, general corrosion thinning and laminations. (Note that both T-scan and C-scan are terms used for scans in which a compression probe transducer is traversed across the surface in a raster pattern to produce plan-view maps showing the positions of embedded flaws or far wall corrosion. The only difference is that T-scan is the term normally used when data is displayed by distance (time of flight), whereas C-scan normally displays amplitude information.)

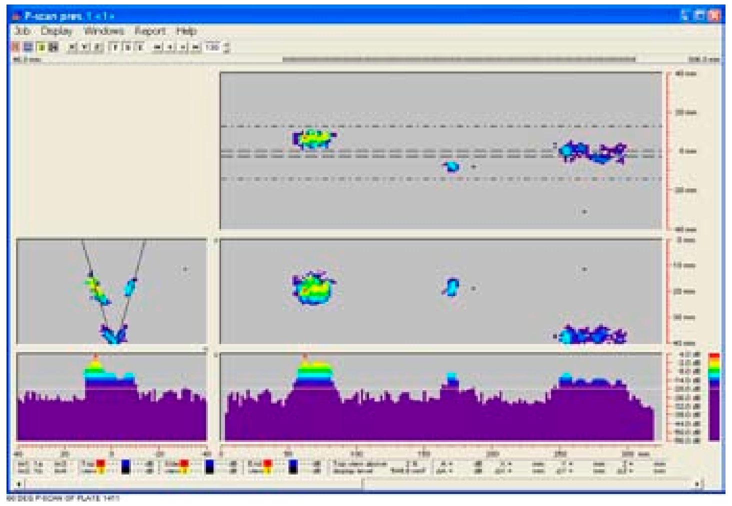
Examples of the displays from these two scan types are given overleaf. The P-Scan system can also be used for TOFD flaw detection and sizing. This is described elsewhere.

TWI has a range of versatile manual and mechanised scanners for use with the P-Scan system.

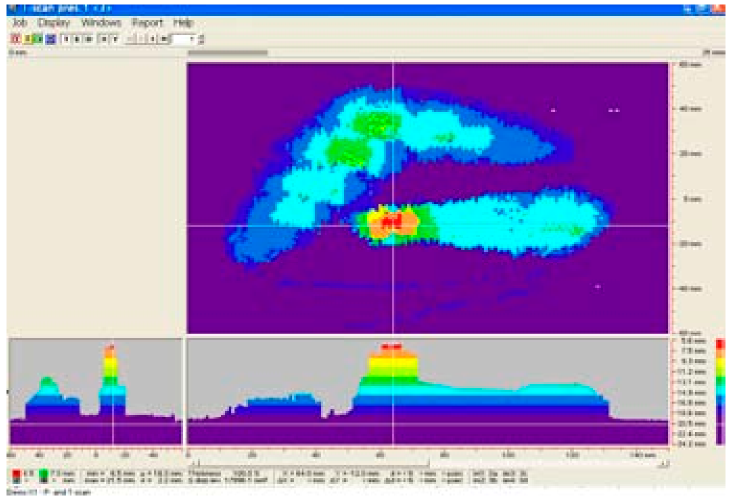
NDT Services from TWI

Selected clients and applications

- Critical phased array flaw sizing on the turret of a FPSO vessel for Petrobras
- Phased array flaw sizing on the Humber and Mardle bridges for the UK Highways Agency
- Phased array boiler inspections for BNFL Magnox
- T-scan corrosion mapping of ship hulls for Ocean Fleets.
- P-scan inspection of welds in gas storage vessels for the British Navy.
- P-scan inspection of girth welds in thick wall Hydrocrackers for Mobil Oil.
- P-scan inspection of seam welds in LPG storage spheres for BP.
- P-scan inspection of offshore platform riser welds for Conoco UK.
- P-scan inspection of offshore riser tie-in “golden” welds for Amoco.
- P-scan inspection for SCC in Ammonia storage tank welds for Norsk Hydro.
- T-scan corrosion mapping of vessels on Ekofisk platform for Phillips Petroleum.



P-Scan display showing weld flaws in plan-view (top), longitudinal (right) and transverse cross-sections (left).



T-Scan corrosion map (top) with longitudinal and transverse section views through areas showing major thinning

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TWI WORLD CENTRE FOR MATERIALS JOINING TECHNOLOGY

NDT Services from TWI

Digital Radiography / Computed Radiographic Tomography

TWI

Description

Computed tomography (CT) is a non-destructive X-ray inspection technique that produces high-resolution 3D images of samples. After reconstruction the sample can be viewed from any 3D angle, sliced in any direction, measured and even animated in a virtual workspace. This enables detailed analysis of the internal structure of a wide range of components. TWI has acquired the X-Tek 450 keV and 75 keV systems.

In CT the sample is X-rayed from a range of angles over 360 degrees. The TWI installation has a manipulator with 5 degrees of freedom so that all areas of the component can be covered. The X-Tek CT reconstruction engine uses the X-ray images to calculate the density at all points within the volume to create a 3D model of the component. The model can be rotated and viewed from any desired position and angle.

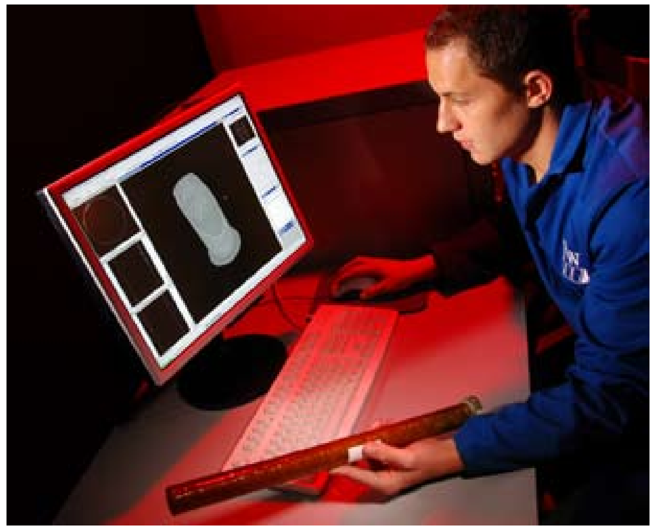
CT enables complex 3D analysis of the structure of components. It can be used to:

- Verify complex internal structures
- Isolate and inspect internal components
- Measure dimensions and angles within the sample without sectioning it
- Automatically detect and measure internal voids / volumes ·
- Remove / strip external surfaces from view to ease inspection

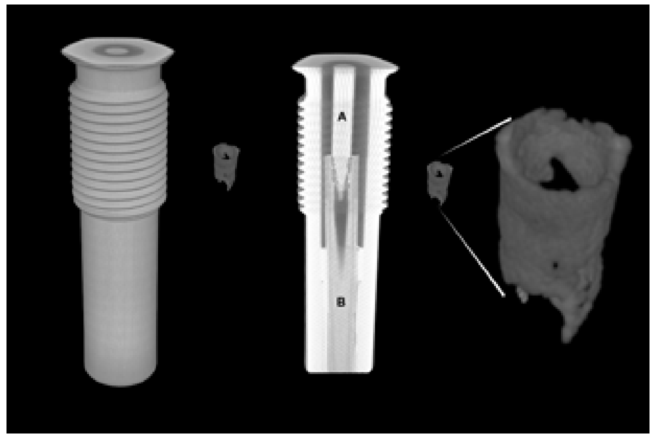
Selected Applications

TWI uses CT to inspect a variety of safety critical components:

- Small machine components such as valves of various types.
- Gauges.
- Sensors.
- Turbine blades, etc.



The operator here is looking at a CT image of the GFRP pipe that he is holding. The task was to locate impact damage. The image shows how CT can be used to ‘cut away’ parts of the component.



CT images of a glow plug. They demonstrate how CT can be used to reveal internal details of a component. The task was to determine the quality of the solder layer in the tapered hole between components A and B. To the right of the component in each view is a smaller image that has been expanded on the extreme right. Thes shows areas where the solder has not wetted the components.

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NDT Services from TWI

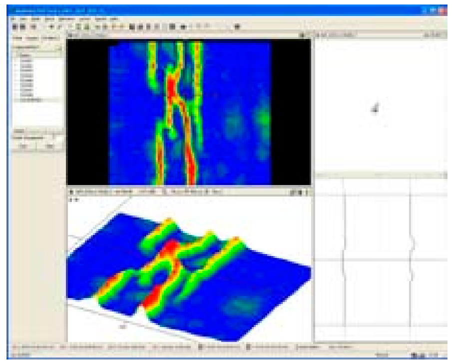
Eddy Current Testing

Description

Computerised systems. TWI owns two R/D Tech® Olympus MultiScan MS5800 computerised eddy current systems. These are used for the detection and sizing of surface breaking flaws in any conducting material. The principal advantages of eddy current over ultrasonic flaw detection are the faster scanning speed and the fact that no coupling fluid is required. Furthermore, it can be used through surface coatings up to a few mm thick, whereas ultrasonics can only be used through relatively thin layers (a few hundred microns).

The Olympus MultiScan MS5800 Eddy Current System

The MS5800 is a multi-channel unit for use with array probes with up to 32 coils. It is operated under the control of MultiView™ software. Output can be in the form of a colour-coded map (a C-scan), where the severity of any flaw is indicated by colour. The data can also be presented in the form of isometric views of the component as shown below.



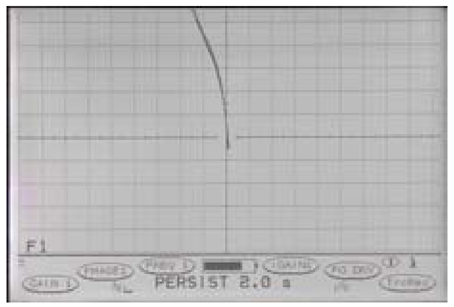
MultiScan output showing stress corrosion cracking in plan (top) and isometric (bottom) views

The probe can be manipulated in a robotic scanner, whose position is fed back to the computerised data acquisition system. However, complex shapes can also be inspected in a single probe pass without the need of scanners or robotic systems.

Conventional systems. TWI also owns several GE Hocking Phasec 2d portable dual frequency systems. One is shown below being used with a pencil probe to inspect for cracking at the edges of bolt-holes in a Ti alloy turbine disc. A typical output with a flaw indication is also shown.

Phasec 2d portable dual frequency eddy current inspection system in use for inspecting a turbine disc

6MHz eddy current pencil probe



Phasec 2d spot display showing flaw indication

Selected clients and applications

TWI is using its eddy current systems for many applications, typical ones being:

- Inspection of friction stir welds.
- Testing gas turbine blades for Rolls-Royce.
- Testing nozzle welds in nuclear reactor pressure vessels for power generation utilities. In this work, TWI is using the ability of the system to cope with complex geometries.

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NDT Services from TWI

Laser Shearography

Description

Laser Shearography uses the coherent, monochromatic properties of laser light to generate speckle patterns.

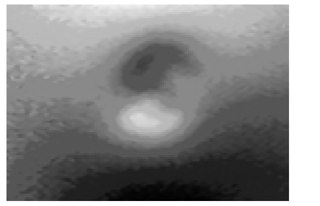
The component to be inspected is illuminated by the laser. The surface reflects the light creating a speckle pattern at the viewing plane, which can be processed to provide information such as the presence of defects, material degradation or residual stress.

The system records the speckle pattern from an unstressed component surface. The image is recorded using a video camera, digitised and stored on a computer. The surface is then stressed and a new speckle pattern generated, recorded and stored.

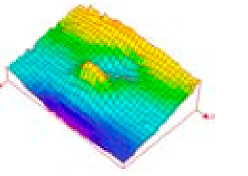
The computer subtracts the speckle patterns from each other, thus forming an image made up of series of characteristic black and white fringes, representing the surface strain in the area of interest. If a defect such as a void or disbond exists, this will affect the surface strain and the defect can be revealed by the fringe pattern developed. This can be processed further by the computer to generate an unwrapped image and a 3D strain map, making the fringe pattern easier to interpret by the user.

TWI owns a Laser Optical Engineering SM 1200 Strain Mapper. This is unique in that it can separately resolve in-plane and out-of-plane strain through the use of a novel dual laser system. This is especially useful when it is necessary to differentiate between faults that produce mainly out-of-plane strain, such as skin to core disbonds, and those that produce mostly in-plane strain, such as cracks.

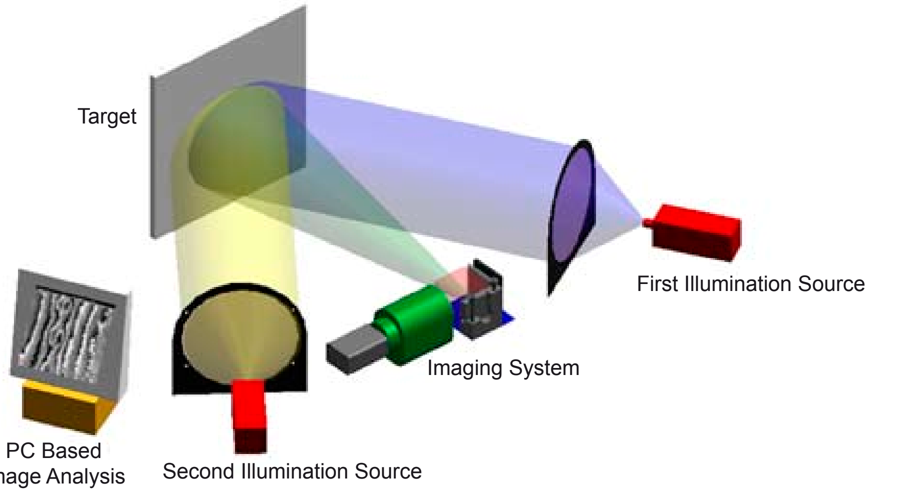
Fringe Pattern



Unwrapped Image



3D Strain Map



Schematic showing the unique dual laser system

Applications

TWI is using its SM 1200 in two major collaborative projects funded by the European Commission.

Sure2grip (www.sure2grip.com) is concerned with the development of an integrated NDT system for inspecting joints in GFRP pipes. The intention is to be able to detect both initial and in-service flaws, such as:

- Build Damage (BD) in the form of weak bonds.
- Accidental damage (AD) in service, in particular Barely Visible Impact Damage (BVID) caused by high velocity impact by solid objects.
- Environmental degradation (ED) caused by ultra-violet exposure or salt water osmosis.

Renewit (www.renewit.eu.com) aims to develop an integrated NDT system to inspect wind turbine blades. Shearography will be used to detect impact damage, in particular defects in the skin-to-foam interface.

Laser Optical Engineering SM 1200 laser shearography equipment

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NDT Services from TWI

Long Range Ultrasonic Testing (LRUT)

Description

Plant Integrity Ltd (P*i*), a TWI subsidiary, makes and operates the *Teletest Focus*™ LRUT system. This is used to inspect pipe in order to detect corrosion and other flaws. It is able to transmit ultrasound many metres (typically 30m) along the pipe in both directions from a 'tool' comprising a 5-ring transducer assembly that is clamped around the pipe by an inflatable collar.

The transducers generate guided ultrasonic waves in the pipe and detect signals reflected from any flaws present. The location of these along the pipe is determined by the time of flight of the ultrasound.

LRUT comes into its own when the bulk of the pipe is inaccessible (insulated, buried, elevated on racks, etc.). In these cases access to the pipe's surface is only required over a length of about 1m in order to mount the transducer collar.

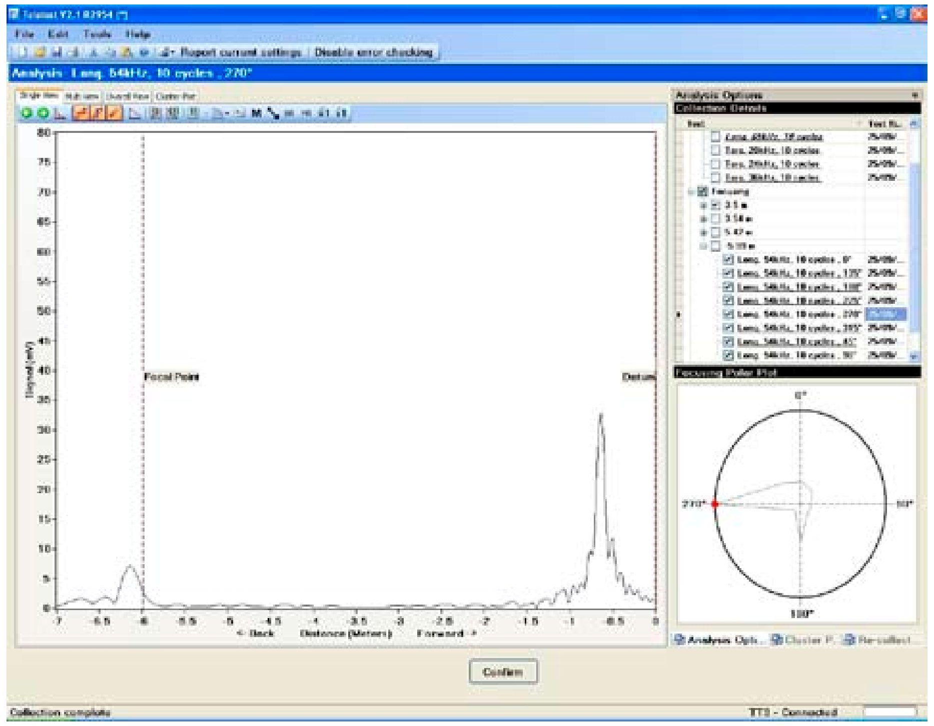
The philosophy behind the new *Teletest Focus*™ equipment has been to produce a lightweight, field-manoeuvrable, high-productivity system in order to maximise return on capital investment. The flaw detector is powered by an integral battery and the one-piece carbon fibre composite collars, which are 40% lighter than Mark 1 versions, are automatically pressurised and monitored using a pump 'on board' the flaw detector unit. A self-diagnostic capability ensures that the tool is correctly coupled to the pipe surface.

The 5 transducer rings provide multi-mode capability and are arranged so that 3 transmit longitudinal and 2 transmit torsional waves. The software, which includes a powerful template driven report generator, is designed to simplify the tasks of the operator and to collect the data with a minimum number of keystrokes. It carries out a sweep of frequencies automatically selected on either side of the theoretical optimum for each wave mode. Thus both wave mode and frequency can be optimised.

Teletest Focus™ *Mark 3 tool, flaw detector and laptop - all that is required for a test*

The multiple frequency data can be displayed and compared on a single screen. In addition, the Mark 3 flaw detector is a 24-channel unit, enabling the transducers to be fired as a phased array. This makes it possible to focus ultrasound at a selected position both along and around the pipe. Formerly, it was only possible to locate a flaw along the pipe. Furthermore, it was impossible to distinguish between a widely distributed series of flaws around the pipe and a more concentrated flaw of the same overall cross-sectional area.

Teletest Focus™ *in use for the inspection of buried pipe at a US oil terminal*



View showing focusing output. In this case ultrasound is focused on an indication at a range of 6m and at an angular position of 270° as shown on the polar plot (bottom right

The phased array capability makes it possible to locate a flaw to within one eighth of the pipe's circumference and means that the system has the potential to move from one that can solely be used for screening to one that also has an approximate flaw sizing capability.

Teletest Focus™ is supported by TWI's LRUT Group. They currently have 20 engineers and technicians involved in research programmes concerned with LRUT to a value of 15.5 million euro (US$19.1 million or sterling £10.5 million). Information about these programmes can be found at www.twi.co.uk/lru

Selected clients and applications

Teletest® is widely used in the oil, gas and petrochemical industries. Examples are:

- Insulated oil pipes sleeved in road crossings for Phillips Petroleum in Alaska.
- Offshore risers for ExxonMobil in the Gulf of Mexico and for the Thai State Oil Company in the South China Sea.
- Buried pipes in ExxonMobil's Jay Field in Florida.
- Gas pipelines for PDVSA in Venezuela.
- Slug catchers for Transco in the UK.
- Headers at a gas compressor station for Northern Borders Pipeline in Montana.

24" sleeved road crossing in Alaska

36"dia x 44mm thick gas compression station header inspected using Teletest® to detect corrosion at concrete supports

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TWI

Real Time Micro-Focus X-Ray

Description

Real Time Micro-focus X-ray is an extension of digital radiography and uses related technology to that used for scanning electron microscopy. It enables X-ray images to be viewed in real-time and allows for computerised treatment of the images to enhance resolution or to enable pattern-recognition algorithms to be used.

Its main application is to the inspection of electronic components and small critical parts. TWI has acquired an X-Tek HMX225 micro-focus X-ray system. This is an advanced system, capable of resolving details down to 5µm, and with up to 160 times magnification. It has the following characteristics:

- 5 µm Focal Spot Reflection Target X-ray Source, 25 - 160 kV or 25 to 225 kV, 0 - 2000 µA (non-continuous) 60 or 225 Watt
- 5 axis fully programmable manipulator
- Maximum scan area 480 x 510mm (480 x 680mm in 2 scans)
- Geometric Magnification up to: 160x
- System Magnification up to: 400x
- Feature recognition: down to 1µm

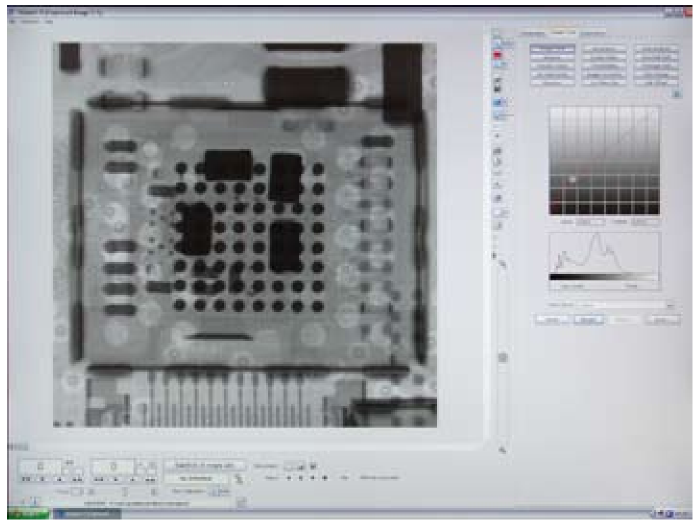
The sample can be manipulated with 5 axes of freedom, whilst continuously viewing the image on a monitor. Defects can be rapidly located, zooming in for detailed analysis.

The system functions as follows. The X-ray source generates a continuous beam of X-rays from a 5µm spot. The beam passes through the sample placed on the manipulator turntable, and casts an X-ray shadow onto the intensifier window.

TWI's X-Tec HMX225 micro-focus X-ray system, also showing the X-ray gun directed at a mobile phone.

The intensifier converts the X-ray shadow into a visible image, which is recorded by a digital video camera and displayed on a monitor. The magnification of the sample depends on its position between the X-ray source and intensifier. Moving the sample towards the X-ray source enlarges the X-ray shadow, showing greater detail. Even when operating at maximum magnification, the ultra fine X-ray spot ensures the monitor image is always sharp.

The associated software enables contrast enhancement, image integration



Micro-focus X-Ray image of a PCB

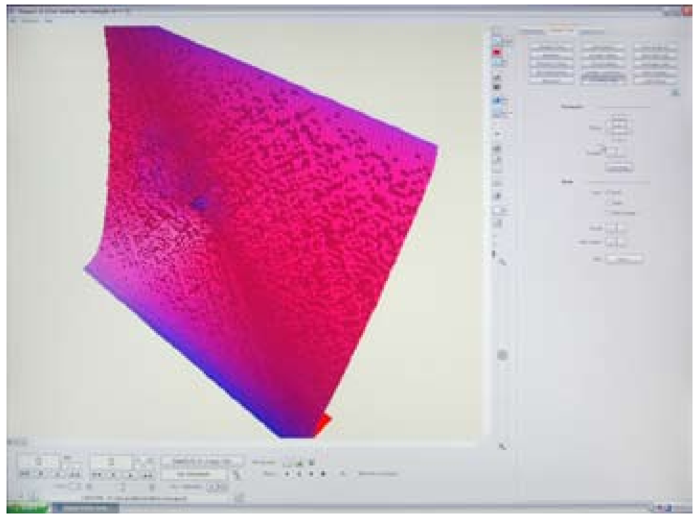
and background subtraction. Special functions, such as automatic die attach void and wire sweep calculations, graphic displays and colour enhancement are available for more critical analysis.

When used for PCB inspection, a so-called 'Golden Image' can be created of a perfect component. The image obtained for a PCB in production can then be subtracted from the Golden Image. Differences indicate possible flaws in the production component. This technique is similar to that used in Automated Optical Inspection (AOI).

Flaws in components are sometimes revealed through the use of a radio-opaque dye.

Applications

In addition to the application of micro-focus X-ray to the inspection of PCBs, TWI also uses it to inspect many small safety critical components particularly for the aircraft and aerospace industries – gauges, valves, sensors, turbine blades, etc. TWI is also currently investigating its use as one technique in an integrated system for PCB inspection. Other techniques for potential inclusion in the overall inspection system are automatic optical in-spection (AOI) and thermal / infrared imaging. This work is being under-taken in the Microscan collaborative project partly funded by the European Commission.



Micro-focus X-ray image showing damage in a plastic composite pipe. This is revealed by flooding the material with radio-opaque dye.

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Non-Contact Ultrasonic Testing

Description

Non-contact ultrasonic testing (UT) has advantages and disadvantages compared to the more common system where the ultrasound is generated by a piezoelectric crystal. The advantages are that:

- No couplant is needed. Thus the reliability of the scanning process is enhanced.
- The component's surface does not require preparation.
- It can be applied when the surface temperature is too high for a contact probe.

Disadvantages are that:

- The transmitted ultrasonic energy is relatively low.
- EMATs can only be applied to conducting materials and laser excitation cannot be used with plastics and composites.

TWI is developing several systems of non-contact UT; electro-magnetic acoustic transducers (EMATs), laser generation and detection and air coupled acoustic transducers. These types of non-contact transducers can be combined to suit particular applications. For example both EMATs and air coupled transducers can be used as detectors for laser generated ultrasound.

EMATs can generate and detect ultrasound in conducting materials. They have two essential components – an electric coil and one or more permanent or DC magnet(s). Current in the coil is cycled at the desired frequency. This induces eddy currents in the test material. These, in the presence of the magnetic field, cause oscillating Lorenz and magnetostrictive forces in the material, thus generating ultrasonic waves.

EMAT wall thickness measurement of boiler tube. To demonstrate the non-contact nature of the EMAT, it is operating through a plastic (non-conducting) ruler.

The reverse processes apply so that ultrasound in the material generates eddy currents, which, in turn, induce currents in the coil. Thus the transducer acts as transmitter and receiver. Depending on the arrangement of the coil and the magnet(s) a wide range of wave types can be generated (normal beam shear, angle beam shear, horizontally polarised shear (SH) plate, Rayleigh and Lamb).

Boiler tube wall thickness measurement is readily carried out using EMATs to generate shear waves at normal incidence. The high temperature oxides that form in the boiler (magnetite and hematite) have excellent magnetoelastic coupling giving higher amplitude signals.

In **Laser UT**, a high power pulsed laser heats a spot on the surface of the test material and rapid thermal expansion generates ultrasound. The frequency content is related to the laser pulse rise time. A Q-switched Nd:YAG laser with a typical pulse duration of 5-10ns generates broad ultrasound up to ~15 MHz. The ultrasound can also be detected optically, as an ultrasonic wave arriving at a surface causes a small displacement, which can be measured using an interferometer.

In TWI's system excitation is provided by an Ultra Compact Folded Resonator (CFR) Q-switched Nd:YAG laser manufactured by Big Sky Laser Technologies and marketed by Quantel. The 50 mJ laser operates at 1.06 μm (near infrared) and is delivered through a 1mm diameter Fibre Optic Launch Adaptor (FOLA). The interferometer is a Quartet manufactured by Bossa Nova Technologies and is capable of operating on unprepared surfaces in an industrial environment.

The interferometer is based on a frequency doubled Nd:YAG 60 mW green laser and operates at 532nm. Different wavelengths are chosen for the generation and detection lasers, so that the interferometer is not saturated by scattered light from the much stronger generation laser.

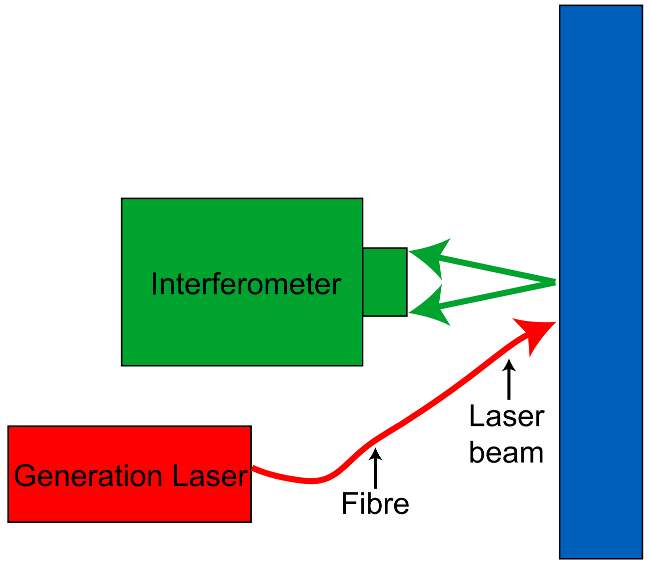
The generation and detection of the ultrasound is coincident. This type of pulse echo is commonly used for testing aerospace composites for thickness and delamination.

The advantage of the Laser-UT systems is that the component is not contaminated by couplant and both generation and detection beams can be optically scanned,

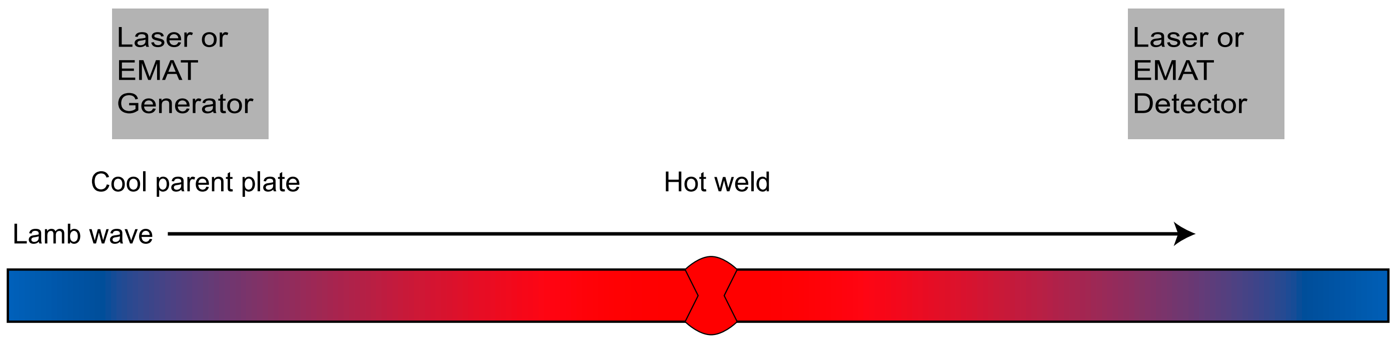
Other applications of Laser-UT include high temperature testing, for example wall thickness measurement on seamless steel tube during manufacture and monitoring microstructural phase changes.

Non-contact ultrasound can also be used for the on-line monitoring of welding processes.

A Lamb wave can be launched in the plate on one side of the weld and transmitted through the hot weld. The amplitude of the detected wave can be used to monitor weld quality. Lasers or EMAT (or a Laser-EMAT system) can be used for this purpose. The EMAT can be placed a few inches from the weld where the plate is relatively cool. Uncooled EMATs can operate continually at temperatures up to 300°C.



Scematic of a laser generated ultrasound pulse echo set up



Typical set up for on line monitoring of welds

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Immersion and Rapid Large Area Ultrasonic Mapping

Description

Typically in large area mapping, a probe is traversed across the component's surface in a raster pattern. A plan-view map is generated showing the positions of any flaws lying in planes parallel to the surface such as laminations. The map that is produced is termed a C-scan. However, in modern computerised systems the full waveform is captured. This means that it is possible to carry out off-line analysis in which other scan types can be displayed:

- A-scan (amplitude v. time of flight) for any given probe position.
- B-scan, which is a cross-sectional view showing the position of any flaws.
- D-scan, which is also a cross-sectional view at right angles to the B-scan view.

The computer collects and stores all the data. Thus data analysis can continue whist the NDT system continues to be used to carry out further scans and to collect new data.

Area scanning systems can be divided between those that operate with contact scanning using a thin couplant layer and those that utilise immersion tanks. TWI has two systems falling into each of these categories.

Contact scanning

NDT Solution's RapidScan2 system is portable and capable of generating high resolution B (through thickness slice) and C (plan view) Scans in a fraction of the time required by existing techniques. Utilising a novel wheel probe containing an ultrasonic array of up to 128 elements, RapidScan2 can be used for manual scanning or can be integrated into automated systems. Applications include composites inspection and plate or corrosion mapping among others.

The DSL Andscan system has a unique manually manipulated R-θ scanner arm. In this, the scanner base incorporates encoders that register the position and orientation of the probe head. However, if the probe is held stationary and the scanner base is moved, this movement is also registered. Thus, by first scanning the complete area that can be covered within the limits of the arm for one base position and then moving the base to new locations, a large area can be fully mapped.

Immersion scanning

TWI has two immersion systems (one in the Cambridge laboratories and the other in South Wales) in which the component to be inspected is immersed in a water tank. The ultrasonic probe is manipulated by a motion controller. Immersion testing offers the following advantages compared with the contact method:

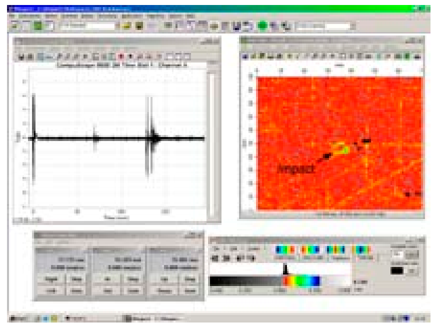
- Water coupling eliminates the variability associated with contact coupling.
- High frequencies, up to 100MHz can be used. Higher frequencies give reduced ultrasonic beam width and much higher resolution. Flaws as small as 0.2mm are readily resolved.
- Focused beams can be generated either by using a phased array or with concave contoured single element transducers.
- Inspection of complex geometries.

The Cambridge based system (shown above right) has very high frequency capability (100MHz), enabling extremely fine focusing. The pulser/receiver operates under the control of Utex Winspect software. This collects the entire waveform and enables the data to be presented in a variety of views

The Andscan R-Θ scanning arm

RapidScan2 wheel probe

The primary tank, data acquisition and analysis systems



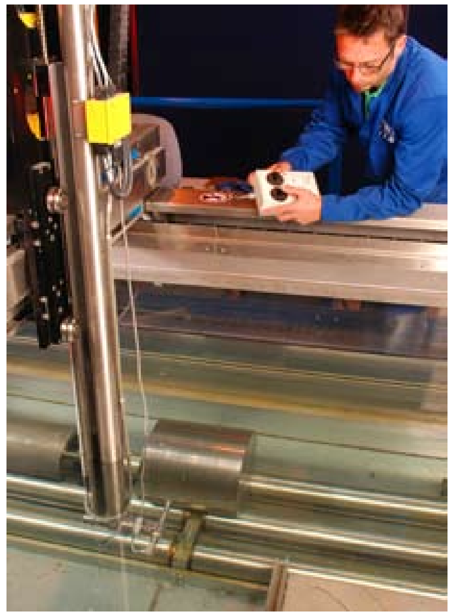
A-Scan (right) and C-Scan (left) outputs from a scan of carbon fibre reinforced plastic aircraft wing component (plan, cross-section, etc.). The probe manipulator has 4 degrees of freedom.

The illustration on the previous page shows the output for an aircraft wing component made from a carbon fibre reinforced plastic tested at the onset of impact damage (A-scan on the right and C-scan on the left).

The photographs on the right show the Ultrasonic Sciences immersion system in South Wales. This has a number of alternative manipulation devices.

- A 750mm diameter turntable enabling discs to be inspected.
- A billet table allowing the rotation of tubular rolls.
- A 5-axis manipulator for manoeuvring the probe head.

It is being used here to inspect a cylindrical metal billet to detect embedded inclusions. The close-up shows the transducer mounted in the 5-axis manipulator. The tank can accommodate components that are up to 2.5m x 1.5m.



Ultrasonic Sciences immersion UT system being used to inspect a cylindrical metal billet to detect embedded inclusions

Selected clients and applications

TWI uses its scanning systems to inspect high added value components for Industrial Member companies. Examples are: -

- Detection of hardening flaws in gear castings for Bosch Rexroth.
- Inspection of electron beam welded rotors for Goodrich.
- Testing carbon fibre reinforced plastic tubes for Hunting Engineering. (This was a challenging application of ultrasound because of the attenuative nature of the matrix.)
- Inspection of adhesive bonds in an aluminium alloy for Thomson Training.
- NDT of friction stir welds for a range of clients.

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NDT Services from TWI

Thermography

Description

Thermography makes use of a camera containing large numbers of sensors sensitive to infrared radiation, which can produce an infrared image and can detect and measure small temperature differences. The image showing these differences can be downloaded to and displayed on a PC, normally as a colour or grey-scale map.

There are two basic types of thermography – passive and active. In passive thermography, the camera is simply pointed at the test piece and from the thermal image a temperature map is constructed.

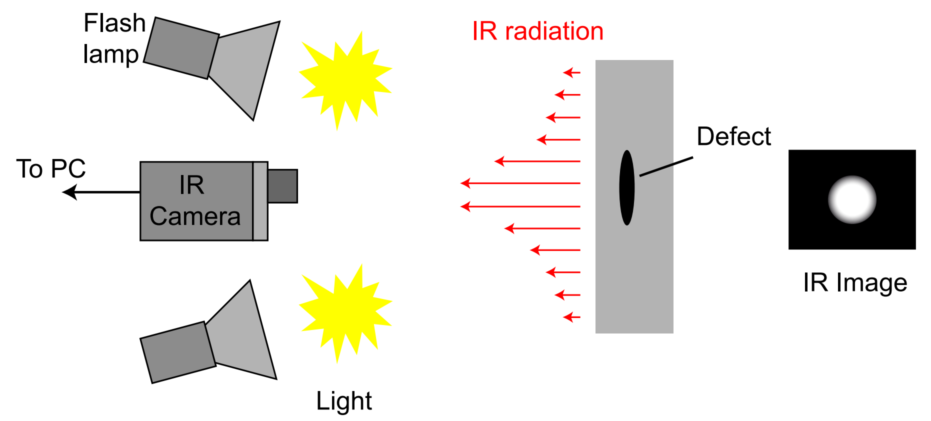
Active thermography involves heating the surface of the object rapidly using an external heat source and observing how the temperature decays with time. Flaws in the material show up by variations in the temperature decay rate. TWI owns systems of both types.

- Passive thermography - Fluke Ti30 infrared camera.
- Active thermography - Thermal Wave Imaging EchoTherm™ Pulsed Thermography (PT) system.

Passive Thermography

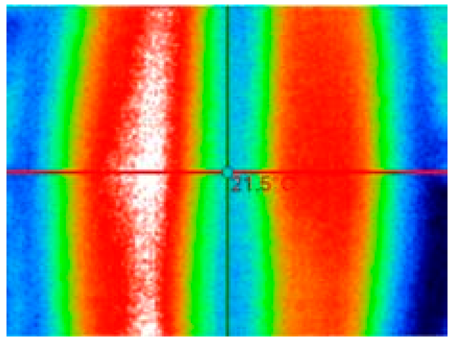
Although the Fluke Ti30 is passive - having no method of inducing a thermal pulse - the data collection system can record temperature changes with time. An application of thermography is to study heat flow during joining.

TWI has used the Fluke Ti30 camera to study electro-fusion welds in polyethylene pipe. A potential defect in such welds occurs when one of the pipes is not pushed fully home in the coupler (so-called short-stab or under-penetration). In such joints the temperature of the coupler in the under-penetrated region will be higher after welding and will decay more slowly.



Principle of pulsed thermography

The Fluke Ti30 camera focused on an electro-fusion pipe joint. The camera is located opposite the electro-fusion coupler.

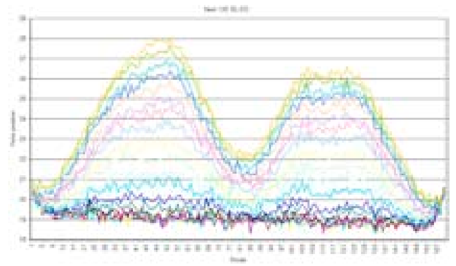


Thermographic image of electro-fusion joint showing under penetration or 'short-stab'. Areas of high temperature indicate the positions into which the pipe should have penetrated.

Pulsed thermography (PT)

PT is an active thermography technique for the assessment of composite materials. It is a high-speed, portable, non-contact and large area inspection technique.

The surface to be inspected is heated by one or more intense light source(s) (~1kW) for periods of 1-25ms. Heat



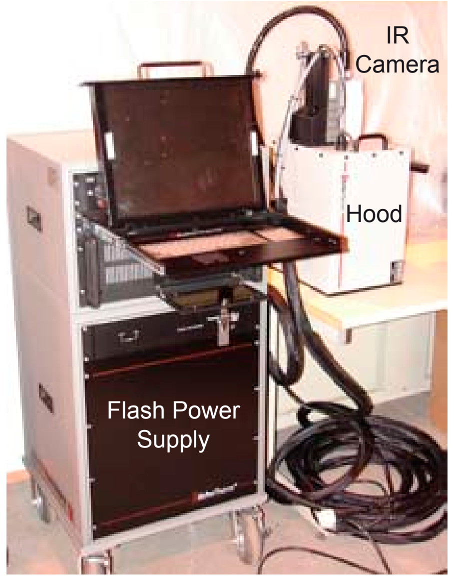
Graphs showing change in temperature with time for a 'short-stab' joint. Images were captured every 30 seconds after welding and the separate graphs show how temperature decays with time. Under-penetration is confirmed by the fact that the high temperatures in the under-penetrated region decay more slowly.

flow into the sample is altered by the presence of any sub-surface flaws (disbonds, voids or inclusions), creating a temperature variation at the surface, which changes with time. These changes are recorded by the infrared camera system, which collects images at a frame rate of up to 60Hz. The software enables the data to be analysed in the following ways.

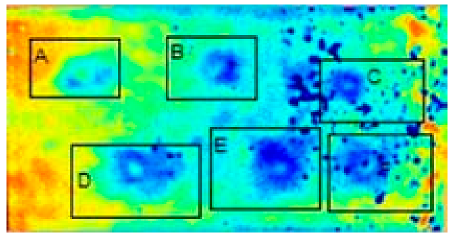
- Time plots of temperature recorded at a single pixel or group of pixels.
- Line profiles.
- 3-D colour or greyscale plots to reveal subtle image features.
- Reconstructed 1st and 2nd order time derivatives.

TWI's EchoTherm™ system is shown on the right above. Inside the hood there are two xenon flash lamps. The hood is placed over the component to be inspected, the lamps are flashed and the camera takes image sequences and the decay data are processed and displayed by the PC.

One of the potential applications is to detect impact damage to wind turbine blades. The image below shows a thermal map of a blade with a number of damage locations being readily detected.



EchoTherm PT system



Thermal map of wind turbine blade showing damage locations

Applications

Aerospace:

- Sandwich panels
- Teflon inserts in graphite/aluminium honeycomb panel
- Carbon / epoxy composites
- Skin-to-core disbonds of Inconel panel
- Delamination / impact damage

Automotive:

- Composite structures
- Paint adhesion
- Spot welds
- Impact damage on composites
- Adhesive bonds

Power:

- Wind turbine blades and vanes
- Thermal barrier coatings for disbonds
- Delamination in composites
- Impact damage
- Coating uniformity

For more information on the services offered in this leaflet, contact:

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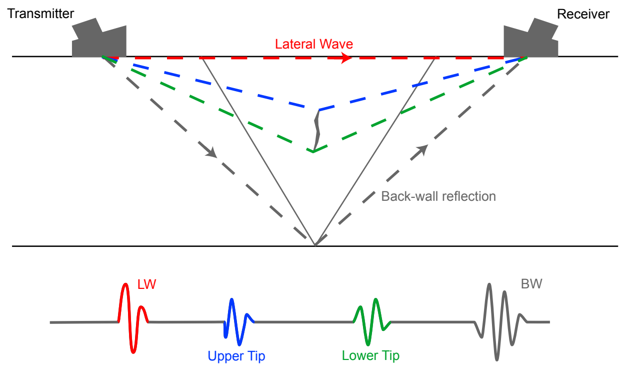
Time of Flight Diffraction (TOFD)

Description

The principle of Time of Flight Diffraction (TOFD) is shown here. Two probes are mounted in an assembly that straddles the area to be inspected (usually a weld). The transmitter probe floods the material with a wide beam of ultrasound. The receiver probe collects a number of signals.

The first signal to arrive is the lateral wave travelling along the material's surface. If any flaw is present, its tips (upper and lower) diffract the ultrasound and the receiver collects signals from these tips. Finally, a signal is received from the back wall. The times of flight of the lateral and back-wall echo signals serve to calibrate the speed of ultrasound in the material. The time of flight of the Upper and Lower Flaw Tip signals enable the positions of these tips and hence the position and through wall height of the flaw to be accurately determined.

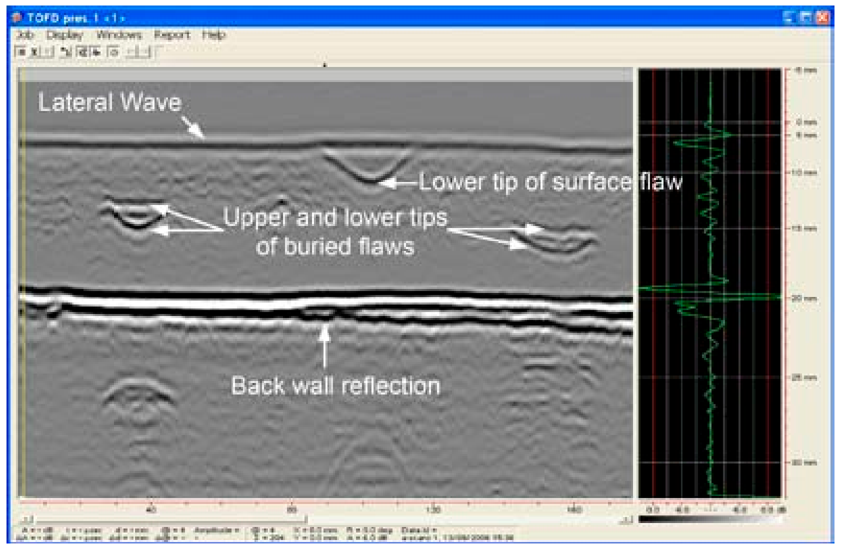
The advantages of TOFD over pulse echo ultrasonics are this accuracy of flaw sizing plus the fact that detailed standards exist for TOFD inspection of welds.



Schematic showing the principle of Time of Flight Diffraction

Zetec Tomoscan III

TOFD equipment in use



TOFD display

TWI has four systems capable of TOFD inspections: two phased array and two more conventional advanced computerised UT systems:

- Olympus NDT's Tomoscan Focus phased array system.
- Zetec Tomoscan III 128 channel phased array flaw detector.
- Sonotron NDT's Isonic 2005.
- Force Technology P-Scan 4+ 8 channel flaw detector.
- Inspection Solutions USB Sector Scan 2 channel flaw detector

TWI has a range of versatile scanners manual and mechanised, which can be used to manipulate probes and can be used with its TOFD systems. The photograph on the left shows a simple hand-held TOFD scanner being used to inspect the girth weld in an offshore riser pipe.

The computer screen display beneath shows a typical TOFD image, in this case produced by the P-Scan instrument.

Selected clients and applications

- TOFD inspection of seam welds in NGL storage bullets in Saudi Arabia.

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NDT Services from TWI

Ultrasonic Bond Testing

Description

One of today's major challenges in NDT is the inspection of composite materials and adhesive bonds. To meet this challenge TWI has acquired the Stavely BondMaster™ 1000+.

This versatile, full multi-mode instrument integrates three inspection methods - Resonance, MIA (Mechanical Impedance Analysis), and Pitch/Catch mode, with the addition of the new RF display mode.

The Resonance mode uses a small, contact probe and requires the use of a couplant. A resonance is set up in the probe, which is affected by changes in the structure beneath the surface. Disbonds are detected by changes in phase and amplitude of probe resonance.

MIA measures the surface stiffness and mass under a single contact probe. Changes in phase and amplitude can indicate bond line flaws. It requires no couplant and is used in conjunction with a spring-loaded holder that ensures constant surface pressure.

The Pitch/Catch method does not require couplant and uses two transducers mounted in a single probe. One transmits either a burst of energy or a sweep across a band of frequencies and the other receives the transmitted sound. Variations in phase and amplitude indicate defects.

BondMaster 1000+ offers the user the ability to select the method best suited to inspect a wide variety of composite materials. It is very light (1.8kg) and well adapted to site use having a six to eight hour battery life. Its display mode can be selected - colour LCD or monochrome LCD for indoor or bright outdoor conditions or a Hi-Brite Electroluminescent (EL) display for normal to dark conditions.

PowerLink™ technology is used to configure the instrument according to the type of test to be carried out. This is done automatically when the sensor is connected. Built-in calibration modes assist the user in optimising the test parameters. A variety of sensors in each of the test technologies are available.

Stavely BondMaster™ 1000+ and hand held contact probe

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NDT Services from TWI

Ultrasonic Modelling

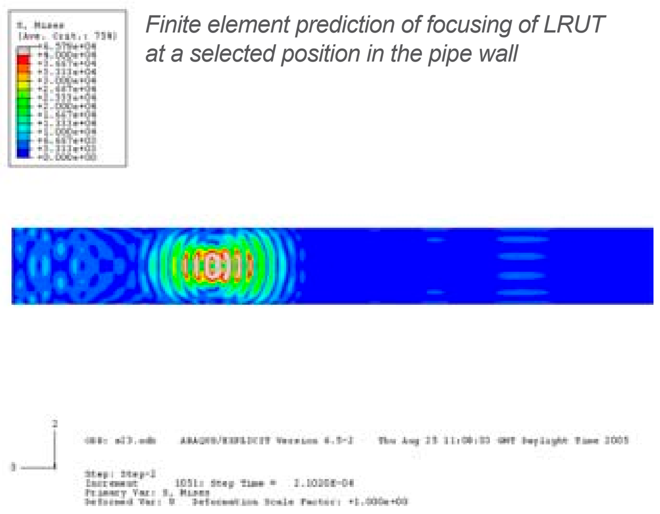
Description

Before taking any sophisticated ultrasonic equipment into the field, it is important to predict the performance of the system on the specific component to be tested. In the past, this has usually been done by carrying out tests on mock-ups of the component in the laboratory. However, more recently numerical modelling of the interaction of ultrasound with the component has found an increasing role. Modelling can be used to reduce the experimental time required and to increase the reliability of on site testing. Modelling can be used for the following:

- Prediction and visualisation of ultrasonic fields
- Calculation of focal points
- Design of phased array transducers
- Analysis of guided waves as used in LRUT and design of phased array focusing in LRUT, including the phasing and power to be transmitted to each module
- Prediction of the interaction of ultrasound with flaws of various types
- Verification of the behaviour of ultrasound in components of complex geometry (e.g. pressure vessel nozzles)

TWI uses three modelling systems.

- Finite element modelling (FEM)
- Acoustic Ideas's Continuum Ultrasonic Modeler™
- CIVA (CEA) – another specialised ultrasonic modelling package



Finite element prediction of focusing of LRUT at a selected position in the pipe wall

Finite element modelling

For many years now TWI has been utilising the Abaqus finite element package to conduct stress analysis, predict heat flow and, in particular to model ultrasound. Examples are:

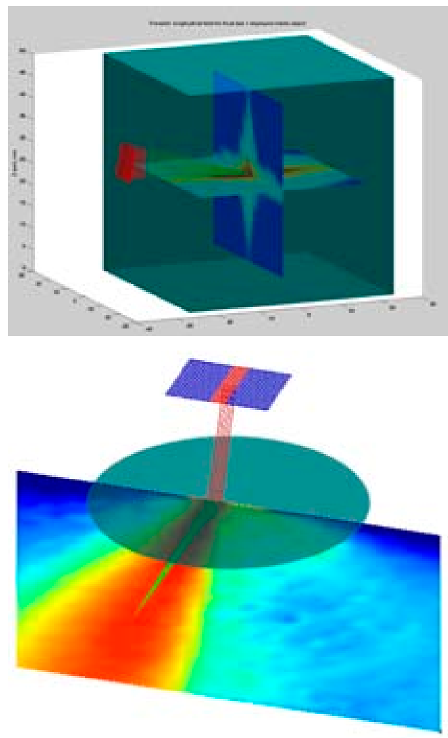
- Guided wave applications
  - Rails
  - Straight pipes
  - Pipes with branches
  - Pipes with bends and elbows
  - Phased array focusing in LRUT (see diagram showing a visualisation of focusing below)
  - Chains
  - Rods (square, round, L shaped)
- Conventional UT of turbine blades

Finite element analysis has the advantage that it is the most accurate method against which other methods can be calibrated. Its principal drawback is that it is extremely demanding in terms of computer time, since accurate modelling of ultrasound requires 8-10 elements for each wavelength.

This means that, at typical frequencies for conventional UT of 1-5mHz, the element spacing should be not greater than 0.2-0.8mm. A 3D model of a reasonable sized component may therefore require a prohibitive number of elements and even for a 2D model the number can be very large. The problem becomes more manageable for guided waves where frequencies are an order of magnitude lower.

Acoustic Ideas Continuum Ultrasonic Modeler™ is a general-purpose ultrasonic modelling package providing the following:

- Calculation of focal laws
- Accurate modelling of ultrasonic fields, including diffraction



Three-dimensional field models using Acoustic Ideas Continuum Ultrasonic Modeler™. The top image shows the intersection of a focused beam generated by a phased array transducer with vertical and horizontal planes. The bottom image shows a detailed visualisation of a focused beam.

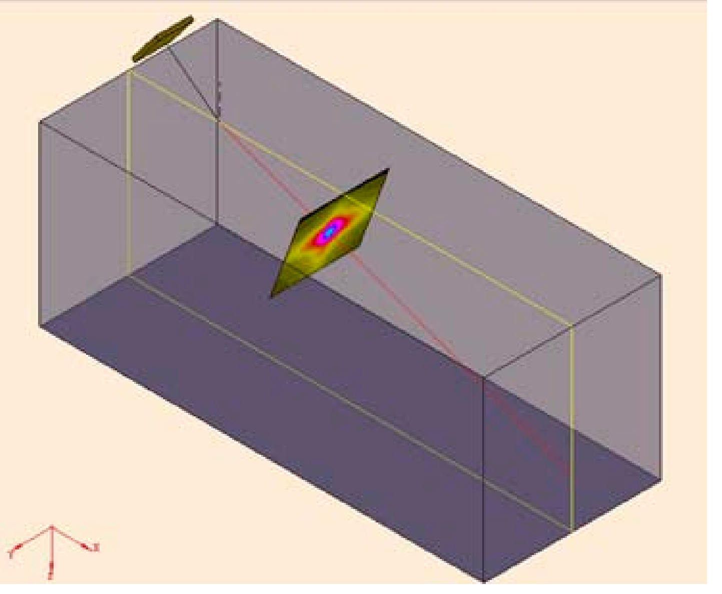
- Visualization of ray paths in multilayer components
- Accurate calculation of scattered echoes from defects
- Interpretation of experimental or field data
- Development and verification of transducer designs

CIVA is also a general-purpose package developed by CEA (France). It is able to model real life inspection scenarios to improve the design of inspection procedures.

A wide variety of geometries can be used including CAD representation making it a very versatile tool. All major ultrasonic transducer types are represented including phased array types and twin crystal probes. CIVA is also able to model a wide variety of engineering materials including those with anisotropy.

Furthermore the user can investigate a wide variety of flaw shapes and sizes, including the standard calibration defects (SDH, FBH, slots etc.) and complex CAD defined rough cracks.

Currently the NDT department of TWI is engaged in the validation of the sound field created by the model against previously validated British Energy models and experimental results.



CIVA image of sound field created by a square crystal inside an isotropic medium

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