Innovative Technology and Science Limited

Tariq Sattar
Business focus

1. Non-Invasive sensor and instrumentation development for non-intrusive measurements, structural condition monitoring

2. Development of innovative Automated and Robotic NDT Systems for in-service inspection in hazardous environments

Currently participating in more than 10 EU projects as coordinator, SME or RTD, coordinating two DEMO projects
Robotic NDT with wall climbing and swimming robots

1. Brief introduction to our wall climbing robots and rationale
2. Underwater robots for storage tank inspection
3. Underwater robot for nuclear pressure vessel inspection
4. Underwater robot for mooring chain inspection
5. Underwater robot for pipeline inspection
6. Underwater systems for condition monitoring of tidal wave generators, ship cleaning
Robotic Non Destructive Testing (NDT)

R&D of Mobile robots to

- Provide access to test sites on very large structures
- Provide access to test sites located in dangerous and hazardous places
- Deploy a range of NDT techniques to find cracks, extent of corrosion, weld defects, etc.
• Reduce inspection costs, outage times during planned outages
• Provide in-service inspections where possible to eliminate outages
Examples of industrial inspection tasks that will benefit from Robotic NDT

1. Gas boiler inspection
2. Weld inspection on cargo container ships
3. Internal inspection of petro-chemical storage tanks
4. Inspection of storage tanks for Floating Production Storage of Oil (FPSO)
5. Aircraft fuselage and wings
6. NDT of complex shapes
7. Wind turbine towers and blades
8. Weld inspection of Nuclear Pressure Vessels
Internal inspection of Gas Boiler in Power Plant

Example where Robotic NDT would save time and cost and improve HS

90m tall boiler, tapered at the bottom
Internal inspection of gas boiler using platforms
Scaffolding inside boiler
Scaffolding inside boiler
Inspection of welds – e.g. hulls of cargo container ships during construction, reduces NDT time and cost by eliminating scaffolding erection.

External dimensions:
30m height,
30m width,
300m length
perimeter area
200,000 m²
(0.2 sq. km).

Inspect vertical and horizontal weld lines.
Complete system development with focus on providing ACCESS to large safety critical infrastructure for the purpose of automated NDT and inspection

Wall climbing robots for NDT and inspection of ship hulls, wings & fuselage of aircraft, dams, bridges, buildings
Advanced Wall climbing robot for the inspection of welds on large steel structures e.g. cargo container ships

- Permanent magnet adhesion
- Wireless control
- Ultrasonic phased array NDT
- Wireless data acquisition
- Mass 35 kg
Advanced Wall climbing robot for the inspection of welds on cargo container ships
Ultrasound NDT Climbing Robot – adapts to surface curvatures (concave or convex)
Climbing Robot Cell for welding and NDT - CROCELLS

- Team of climbing robots

- One performs Electric arc welding by profiling seam with a laser system

- A utility robot follows the welder and carries the wire drum and feeder

- A tug robot aides the welding robot

- An NDT robot tracks the welding hot spot and performs weld inspection with phased array ultrasonics
Innovation Award 2010, Highly Commended – The Emerald Industrial Robot International Journal
Wall climbing robots for NDT, inspection and surveillance

- Wireless control
- Vision and imaging systems
Payload
4 kg with a
30cm x 30
cm robot
footprint
STORAGE TANK INSPECTION
In-service inspection of petro-chemical storage tanks with mobile robots – RobTank project

Worldwide, over 218,000 petrochemical storage tanks and 53,000 large storage tanks with diameter > 50m are mostly inspected with outages. A large 100m diameter crude oil tank can be out of service for up to 9 months.

Existing tank floor inspection activities

- Preparing recipient tank
- Moving contents to the recipient tank
- Opening the tank under inspection
- De-gassing the tank
- Cleaning the tank – Sludge removal
- Manual Inspection conducted by personnel
- Closing the tank after inspection
- Refilling the tank
- Checking seals, vents, hoses etc.

Average Total Cost €70000

80% of cost is opening and closing the tank.
CLEAN TANKS
Diameter 2 to 20 metres, fixed roof. Visual inspection, a few ultrasonic thickness measurements.

Crude oil tanks floating roofs, dia 20 - 100 metres, carbon steel. Floor thickness of 6-12.5mm, Preparation: 6-9 months .Another 3-6 months to clean .

Visual inspection followed by MFL. UT final method to validate the problem areas.

Manual tank floor inspection, underside corrosion defects
In-service intrusive inspection

Mobile robot, RobTank, enters through manholes on the floating or fixed roof of a tank

- Can enter minimum manhole 300 mm diameter
- Designed for intrinsic safety
- Carries payload of ultrasonic NDT sensors
- Inspects floor and walls of a tank
1. Innovation Award 2004 – The Emerald Industrial Robot International Journal
Mapping of floor defects using rotating bulk wave ultrasonic technique

- Drain outlet
- Welded stud
- Top of tank wall
- Tank floor weld
- Corner of tank floor
- B-Scan line with origin at centre

Drain outlet reflection in tank wall

180° 270°
An amphibious swimming and floor moving mobile robot to inspect storage tanks

FPSO Robot
Scanning Arm mounted on this face

Ultrasonic range finders for detecting walls and strengthening plates

Two motors, one for wheel motion, the other to change direction of wheel

Thrusters
Automated weld following along stiffener plates and walls using range sensors. NDT with ACFM and Creep waves
 FPSO swimming robot in a water tank. Vertical motion by depth sensor feedback and buoyancy control. Horizontal motion with two thrusters.

 FPSO swimming robot in a water tank. Robot descends to the tank floor and moves on the floor to follow weld lines along stiffener plates and walls.
FPSO
Swimming and floor inspection
Inspecting Reactor Pressure Vessels (RPVs)

- 450 nuclear power plants around the world with 210 in Europe
- 8% increase to 2010 and then doubled and trebled by 2020 and 2030 respectively
- Eight currently operating nuclear units are over 40 years old
- RPVs contain water under high pressure, constructed of thick steel ring, dome and nozzle sections welded together. Become brittle with age, exposure to radiation and are susceptible to stress-corrosion cracking.
- Operator cost 0.8 million Euro per day for a planned outage and for an unplanned outage it may be up to 1.6 million Euros per day.
- Outage duration for top 10 performers had fallen from 50 days in 1986 to 20 days in 2004 and has remained nearly steady since then.
RPV Circumferential and Nozzle welds

- Upper shell
- Nozzle weld to safe end
- Circumferential weld
- Lower shell
- Bottom head
- Nozzle weld to shell
- Upper shell
- Nozzle weld to safe end
- Circumferential weld
- Lower shell
- Bottom head
- Nozzle weld to shell
Current method of inspection uses large robots to do inspection – robot transported and assembled on site before immersion in RPV

- Require large and heavy robots with a central mast costing millions, manual set up time, tying up of polar crane needed for other tasks
Drawing of the pipe crawling robot and scanning arm inside a nozzle
Nozzle inspection robot

- **SA1** - electronic compartment - main body of the unit. Interfaces electronic elements that actuate the ROV plus the pan/tilt camera for visual inspection inside the RPV nozzle.

- **SA2** - interfacing structure that holds two underwater motors that actuate the tracks (SA4) and provides the necessary rotary actuation to the nozzle inspection arm.

- **SA3** - actuation module forces simultaneously the tracks towards the nozzle. The RPV nozzle is an axis symmetric shape with continuously variable diameter, the tractor support (SA3) provides suspension capabilities in order to cope with the nozzle diameter change.

- The tracks are 400mm in length, 100mm in width and height.
Wall climbing robot

Submersible robots for weld and corrosion testing in nuclear pressure vessels

- 2DC motors for drive actuation
- 3 triangular suction cups for adhesion to wall - Use air motors for suction cup actuation
- Tested with negative buoyancy
MOORINSPECT
Development of an advanced medium range ultrasonic technique for mooring chains inspection in water

MoorInspect 286976 FP7-SME-2011-1
The project:
Mooring chains for FPSO vessels are extremely critical.

Loss of anchorage is a disaster - rupture risers that bring oil up from the wells.

Inspection of mooring chains is rarely done. Divers do not operate near a chain because of very high dynamic forces.

Need identified by:

SBM (Single Buoy Moorings), installs and services mooring installations and operates a fleet of Floating Production and Offloading (FPSO) vessels.

VICINAY manufacturer of mooring chains.
Critical failure modes in chain links:

- Fatigue cracks emanating from the internal radius of the chain-link. Cracks can grow to beyond 50% through-wall before causing failure.
- Also some failures at the weld.

- Depth: chain failure occurs near the surface to a depth of 25m, and at the sea bed. Beyond 25m chains are sometimes attached to lighter-weight cable-type ‘ropes’ down to the anchor.

Target performance: crack size and location.
Range of chain link dimensions: Mooring chains used with FPSOs are generally 110mm, 160 or 180mm diameter.
Chain tilt angle: for FPSOs - 45 degrees from platform to mooring point.
Development of prototype inspection robot for operation in water and in air.

- Robot should climb on chain link sizes from 100 to 200mm. Not possible in one equipment, therefore the prototype is designed for sizes beyond 150mm.

- Chain cleaning facility on the inspection capsule not included – not necessary for the northern sector of the North Sea, marine encrustation not a problem.
Progress in modelling:


2. ‘Dispersion curves’ of guided waves propagating along a 151mm diameter solid cylinder - show the presence of a great many wave modes at the lower frequencies. E.g. T-waves at below 100KHz ultrasound in a 6” pipe, only one wave mode (T0,1), in a 151mm solid bar, two additional modes (T0,2 and T0,3).

3. Not known - Effective depth of penetration of the guided wave from the surface of the solid cylinder
4. Guided wave propagation around a right-angle bend concentrates energy around the outer circumference. A problem for chain inspection, since the cracks tend to emanate from the internal radius.

Practical work

- Guided waves, when circulating the chain in a ‘race track’ procedure are sensitive to notches cut into the inner circumference of the chain link.

- This procedure is being ‘qualified’ by looking at the ‘influencing parameters’ that affect the sensitivity of the test.

- Parameters: guided wave mode; test frequency; ring spacing and transducer separation.

- Results are very promising - good sensitivity achieved well below the target frequency range of 100-500KHz.
Other systems:

Development of software for control, data collection and automated defect detection.

Defect recognition database - Pattern recognition system using the A-scans derived from the LRUT. Includes de-noising, feature extraction, selection and classification.
MoorInspect is a collaboration between the following organisations:

Plant Integrity Ltd (Coordinator and manager)
Bytest SRL
ORME
Robotnik Automation SLL
Sonomatic Limited
iknowHow Informatics S.A.
Innovative Technology and Science Limited
Vicinay Cadenas S.A.
Single Buoy Moorings Inc.

Partly funded by the EC under the Research for the Benefit of SMEs programme. Grant Agreement Number 286976
The PIGWaves solution

The Pigwaves project

✓ Small-sized, umbilical-free neutrally buoyant robot able to swim/float in oil pipelines with internal diameter ranging from 150-350mm.

✓ LRUG collar uses ultrasonic guided waves and time reversal focusing to identify circumferential and axial pipe corrosion and cracks

✓ Robot communicates with base station at entry point to send NDT data and locate position of robot.
Non intrusive condition monitoring of structures

Long Range Ultrasound Guided waves
The TidalSense Project
Condition monitoring of turbine blades

Finished October 2011 followed by the

The TidalSense Demo Project
(coordinated by InnotecUK)
TidalSense Demo
Kick-off meeting
Demo Transducers

Inclinometers, accelerometers, Gyrometers, magnetic field

Torque sensors

IP cameras

Flow Sensor

Monitoring System

Temp, Humidity and DewPoint sensors
Installation of sensors

- The placement of sensors is along all tidal blade surface.
Shore
TSB
CORMAT + Hydro-Buoy
Radio Link
Fibber Optic/Lan Cable
Power Supply
Monitoring cables

CORMAT + Hydro-Buoy
Linear array of 25kHz piezo-electric transducers on the ship hull bottom, near the stern and just above the water line.

Because of the low frequency (long wavelengths) the waves diverge at a large angle from every transducer. So the waves reach every part of the hull wall and the wave energy moves in zig zags down the hull through multiple reflections from the hull walls (waves).
WP1 System functional design, environmental specification and hull section procurement

Mathematical Modelling and software for ultrasonic prevention and detection of fouling on ship hulls
- forces by quasi continuous/continuous waves in a hull on biochemical macromolecules and bacteria in water
- Modelling of attenuation of waves caused by fouling
- measurement of long term attenuation changes in pulsed waves

High power ultrasonic wave system for the prevention of fouling on ship hulls
- Design of continuous wave transducer array
- Design and construction of the ultrasonic generator
- Embedded software for generation of the optimum mode

Pulsed ultrasonic wave system for the detection of fouling on ship hulls
- Design of a transducer array for optimum mode propagation
- Design and construction of the ultrasonic pulser-receiver electronics

System validation through laboratory and port environment trials
CLEANSHIP: “Prevention and detection of fouling on ship hulls”
Grant agreement no.: 312706

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Robotic NDT