Continuous condition monitoring of pipelines and risers

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www.smartpipe.com
The SmartPipe vision

- An on-line system reporting the technical condition of the pipeline through a combination of sensors, degradation models, and analysis tools

- Self-contained, distributed sensors packages with locally produced power and wireless communication
General system requirements

- No interference with laying operations
- Non intrusive sensors
- Low cost, simple, robust
- Lifetime >20 years
- Interfacing to existing sensor technology
- Low power consumption
- Local processing to reduce needed communication capacity
Key parts

Data collection
- Sensors
- Communication
- Power

Data interpretation
- Materials degradation
- Analysis tools
- Database

Decision making
- Technical condition
- Warnings
- Simulations
- Visualisation
SmartPipe

- Lithium batteries
- Thermo electric generator

Electromagnetic communication in pipe

Sensors:
- Wall thickness
- Stress/strain
- Vibrations
- Temperature
- Pressure
- Pipeline position

Sensor, power and communication packages
SmartPipe

**Sensors**
- Ultrasound wall thickness measurement
- Strain gauges for measuring deflection and internal pressure
- Thermistor for temperature
- Accelerometer for measuring vibrations and inclination

**Communication**
- Wireless electromagnetic signal in coating

**Power**
- A package of conventional Lithium batteries
- Thermoelectric generator
Battery packing

- Four cells in series inserted in steel tubes
  - 300 mm length
  - Space available for charge balancing electronics
  - Hermetically sealed to prevent water intrusion
- Five 14.4 V battery packs encased in exterior bracelet
  - 40 cells in total (120% capacity)
  - Close contact to cold seawater beneficial for battery lifetime
- Exterior bracelet can be partially embedded in PP-insulation.
Thermoelectric generator

- For pipes exposed to seawater the thermoelectric generator is capable to generate enough power.
- The communication system will be operational only when there is a hot flow in the pipe
  - No data during installation phase
  - No data in shut-down period
- For trenched pipes an energy storage must be used to get enough power when the electronics is active (super capacitor)

<p>| The preliminary conservative estimates for a single Peltier element module |
|--------------------------------------------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>tot $\Delta T$</th>
<th>Buried 20 % of $\Delta T$ over Peltier</th>
<th>Not buried 50 % of $\Delta T$ over Peltier</th>
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</thead>
<tbody>
<tr>
<td>50 °C</td>
<td>6 mW</td>
<td>35 mW</td>
</tr>
<tr>
<td>70 °C</td>
<td>12 mW</td>
<td>70 mW</td>
</tr>
</tbody>
</table>
Communication

- Electromagnetic wave in the coating
- Inter node distance: 24 m
- Redundancy distance: 72 m (three nodes)
- Carrier frequency: 5 MHz
- Propagation loss: 0.5 dB/meter
- Patent application submitted
Global analysis:
- Installation simulation
- Free-span analysis
- Fatigue (stress range/SN based)
- Global buckling
- Upheavals/snaking
- On-bottom stability

Local analysis:
- Fracture
- Fatigue (fracture mech.)
- Local buckling
- Plastic collapse
- Burst

Corrosion analysis:
- Corrosion rates
- Wall thickness reduction
- Safe operation windows
SmartPipe data management

- Fibre modem or powerline modem
- Host machine Data collection system
- Data base
- Degradation analysis
- Visualisation tools

Sub-sea Cable or optical fibre

Fibre modem or powerline modem

Pick-up antenna on outside of pipe

Fibre modem or powerline modem
Mounting concept

- Mounting in field-joint is the most feasible solution
- Belt with hardware fixed to FBE coating with adhesive and strap.
- Molded into the PP coating
- Standard coating procedure
Demonstrator

- 24 meter long 10” pipe with 70 mm PP insulation
- 4 sensor belts with communication units distributed along the pipe. In addition one anode pad
- Belts mounted in field-joints on top of FBE coating
- Produced in February 2009
- Tested in May 2009
Demonstrator

Summer 2009
”Reeling” test at Bredero Shaw 090625

- 4 cycles bending to radius of 8,225 m and straightening
- No cracks or fractures in PP coating
- No problems in any of the installed sensors occurred during the test
”Reeling” test – strain gauges

- Belt C: no sign of reduced contact with steel surface after 3 ”reeling” cycles
Reeling test - Ultrasound

- 4 ultrasound transducers tested
- No signs of reduced contact with steel surface
- No signs of reduced energy in reflected signal
Temperature test at SINTEF 090914

- Heated oil circulated in closed test pipe
- Test temperature 20-140 °C
- No functional problems discovered with sensor system or interfaces
- Strain gauges will relax when Tg of glue is passed
SUMMARY

😊 Sensors and electronics survives field joint moulding and reeling

😊 Less than 2 minutes required to install the sensor hardware on the pipe.

😊 Antennas are successfully installed.

😊 The electromagnetic waves were successfully transmitted in the coating, and signal loss was as previously modeled.

😊 Transition to an industrialized production and mounting procedure seems feasible.

● Alternative glue must be used for operating temperatures over Tg of PP adhesive
Where are we today?

- Application for Phase 2 to be submitted autumn 2009
- More companies are welcome to join in Phase 2
The consortium