Use of Non-Intrusive Ultrasonic Intelligent Sensors for Corrosion and Erosion Monitoring

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 ClampOn

Ultrasonic Intelligent Sensors

- Sand Monitoring
- PIG Detection
- Leak Monitoring
- Vibration Monitoring
- Condition Monitoring
- Corrosion-Erosion Monitoring

Software/Service

- Sand Management
- Well Collision Detector
- Distributed Monitoring Systems
- Online Erosion Modeling  Topside & Subsea
Topside & Subsea

- Non intrusive
- Passive acoustic
- Common hardware
- Digital signal processing
- Noise cancelling
- Superior S/N ratio
Going Subsea means new Challenges

- Subsea Trees
- Subsea Pumps
- Subsea Processing
- Subsea Manifolds
- Subsea Templates
- ROV Tie-in Systems
- Risers
- Pipelines
Quality / Lifetime

ClampOn’s instruments are manufactured according to the highest industry standards.

- Sensor electronic is hermetically sealed in titanium body
- MTBF/ Lifetime is more than 30 years
3 axis vibration monitoring

Upgraded electronic hardware enables us to monitor vibration in all three axis simultaneously as the instrument is monitoring for other applications.

Frequency: 0-1000Hz, Sensitivity: 1mg
Custom Solutions

Portable subsea monitoring system with data logging
Custom Solutions

Retrofit sand monitoring, signal integration, one year power by battery
ULTRASONIC INTELLIGENT SENSORS

The use of Non-Intrusive Ultrasonic Intelligent Sensors for Corrosion and Erosion Monitoring

Cost effective solution for assessing wall thickness loss in pipelines - quantitatively - using Guided Wave technology to optimize output
Presentation Layout

ClampOn DSP Corrosion-Erosion Monitor

- Introduction and Background
- System properties
- Selected results
- System layout
- Subsea Installation Options
- Conclusion
Current State-of-the-Art

- Most pipeline assessment systems are based on spot measurement technology, involving a large number of transducers.
- The few path-based systems available provide qualitative rather than quantitative assessment of damage.
- More often than not, intrusive systems are used to assess the corrosive nature of flow in pipelines using coupons, etc.
Applications for Corrosion Erosion

- Separators – large tanks
- Pipe lines (Straight pipe sections)
- Pipe bends
- Y-or T-joints
- Risers & splash zone
- Any type of metal
- Can also be combined with monitor particles
- Topside and Subsea
Applications ClampOn CEM

- Even though the most common application is wall thickness measurement of pipe wall, the CEM can be used in several other areas:
  - Can be mounted on reducers with changing pipe diameter and wall thickness.
  - Thickness characterization on aged boiler tubes
  - Analysis of adhesive bonds
  - Corrosion monitoring on tanks
  - All other metal structures with the need for thickness assessment...

- Flow conditions: water, oil, gas, multiphase, none.
- Large temperature area...
System in the field

ClampOn CEM Electronic Unit

Protection Cover

Transducers under the Protection Cover
System in the field
Working Principle - Lamb Waves

ClampOn DSP Corrosion-Erosion Monitor

- AGLW = Acoustic Guided Lamb Waves
- Named after Horace Lamb, who discovered the waves in 1916
- Also called Long Range NDT
- The pipe wall will force the transmitted signal into a given shape and form (mode generation)
- Analytical inversion of acoustic data to obtain relevant thickness information
• Transducers can be mounted on the outside of coating <1mm /0.04” thickness

• Measures WT between the transducers in “line of sight”
• Resolution/sensitivity better than 1% of WT
• Signal is Robust and will not break down
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What do we measure?

- Measures WT between the transducers in “line of sight”
- Resolution/sensitivity better than 1% of WT
- Signal is Robust and will not break down
The figure illustrates the area covered by a pair of transducers.

Beam divergence allows the CEM to „see“ a large area.

A matrix of transducers deployed on a region of pipe can provide comprehensive coverage.

The larger WT the larger the coverage area is.
ULTRASONIC INTELLIGENT SENSORS

CEM - Coverage Area

- OD pipe – 8”
- Separation 700 mm
- 6 Transducers set-up

Total Coverage:
- \( \approx 60\% \)
- Each path width is 70mm
ULTRASONIC INTELLIGENT SENSORS

- CEM - Coverage Area

Pipe Unfolded

- OD pipe – 8”
- Separation 700 mm
- 6 Transducers set-up

Total Coverage:
- ≈ 60%
- Can be calculated by Software
Comparison – Coverage Area

**COVERAGE AREA –**

**THE MEASURED AREA THAT THE SYSTEMS ARE COVERING:**

a) 2 x CEMAT Transducer separated by 600mm.
   
   Coverage area = 35 000 mm$^2$

b) Alternative 14 spots (el 5mm) each covering 19,5mm$^2$ = 273 mm$^2$

c) Alternative 8 spots (el 12mm) each covering 113mm$^2$ = 904 mm$^2$

OR

d) 8 CEMAT Transducer distributed over the selected surface: <65% of the surface, which equals to: 187 000 mm$^2$.

= Large coverage with less transducers/equipment
Detecting average wall thickness

Three separate scenarios:

- Highly localized pit exerts a very small (< 1%) effect on average wall thickness → undetectable

- General erosion exerts a noticeable (> 1%) effect on average wall thickness → detectable

- A highly localized groove will be detected IF its effect on average wall thickness is > 1%
Interference

- What may affect the measurement technique?
  - fluid loading
  - surface roughness
  - the presence of epoxy coatings
  - temperature swings

- They are all important factors that affect the system, but these have all been fully investigated and accounted for.

- Bottom line is: The CEM measures wall thickness from the shape of the signal – not the amplitude!
The Transducer

- ClampOn have developed their own transducer, called CEMAT, or “dry contact” transducers.

- The CEMAT is Ex mb certified for use in zone 1, for temperatures up to 200°C (T3).

- High temperature transducer is under development for permanent use up to 400°C.

- Transducers are to be in close contact with pipe < 2.0 mm lift off.
System properties

CGV mode

• The system measures the wall thickness loss between pairs of transducers
• The system will have between two and eight transducers in operation
• The sensitivity for wall thickness assessment is around 1% of wall thickness (WT) over the full temperature range
• Can detect small changes as small as 0.1% of WT
• Repeatability is: ± 0.04%
• The system measures wall thickness in REAL time, at user-definable intervals
Independently observed test

Results from erosion on 12 mm plate

Witnessed by BP, Statoil, Hydro and Shell

- 12mm thick plate eroded randomly with a power tool
- Test was conducted and monitored by independent observers
- Predicted thickness loss on day of test was later verified by actual measurements as seen in the figure
Uniform thickness loss
CEM demonstration – uniform thickness reduction

20 to 10 mm uniform thickness reduction
Constant offsets added and 2 spurious readings

THE LEADER IN SAND, PIG AND CORROSION-EROSION MONITORING
Example – Detecting general corrosion

- General corrosion was simulated by grinding on a 1 x 1 m and approximately 22 mm thick plate.
- Corresponded well with results obtained from handheld UT gauge.
- Figure showing 2 grinding runs, showing an average loss of 3.3% and 1.2%.

![General corrosion](image-url)
Example – Detection “pitting corrosion”

- Pitting corrosion was simulated by drilling small holes in a 1x1m and approximately 22mm (0.87”) thick steel plate.
- The ClampOn CEM shows a average loss of about 1%
- UT measurements conducted in a thorough manner at 14 points along the measurement path showed no corrosion.
Sensitivity to groove-like defects

Machined grooves on a plate detected

- 10 mm plate
- Measurement method:
  - Micrometer
  - CEM
Weld-root erosion detection

CEM installed on a pair of welds as shown
Weld-root erosion detection

CEM installed on a pair of welds as shown

- ✓ Corroded weld
- ✓ OK weld
ULTRASONIC INTELLIGENT SENSORS

THE LEADER IN SAND, PIG AND CORROSION-EROSION MONITORING
Verification of Stability
CEM system tested with heating & cooling

Standard deviation: 0.02mm
Temp. range 10 - 170°C
Acid corrosion test

- An acid solution was injected to the pipe to emphasize corrosion.
  - PH level was regularly checked to maintain a steady corrosion.
  - Temperature cycled to increase/decrease corrosion and check stability.
  - Showed good resemblance with UT measurements.

<table>
<thead>
<tr>
<th></th>
<th>CEM</th>
<th>UT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottom</td>
<td>1.77</td>
<td>1.63</td>
</tr>
<tr>
<td>Top</td>
<td>0.48</td>
<td>0.48</td>
</tr>
<tr>
<td>Top – Bottom 1 (1 – 2)</td>
<td>0.79</td>
<td>1.27</td>
</tr>
<tr>
<td>Top – Bottom 2 (1 – 4)</td>
<td>1.01</td>
<td>1.11</td>
</tr>
<tr>
<td>Top – Bottom 3 (2 – 4)</td>
<td>1.01</td>
<td>0.93</td>
</tr>
</tbody>
</table>
EMAT

- Electromagnetic Acoustic Transducers
- The wave is generated inside the pipe, not in the transducer itself like with classic piezoelectric.

Advantages over piezoelectric transducers:
- Better thermal stability
- No need for acoustic couplant such as silicon → easier to install
- Makes the system relocatable.

Drawbacks:
- Lower sensitivity → need more averaging
- Larger transducer size

Conclusion:
- Proper measurements
ClampOn CEM Subsea

Corrosion-Erosion Monitor

- 3 Models alternatives for CEM -

- CEM for ROV installation
- CEM under insulation/coating
- CEM w/mechanical cover
CEM Subsea System

Main Parts

- Transducers
- Electronic w/PAC unit
- Power

Electronic up to 7 meters from transducers
Subsea CEM

- Allows CEM system to be made ROV installable.
- Design based on existing proven subsea electronic chambers and ROV funnel design.
- CEM electronics placed in a hermetically sealed canister with up to 16 transducers connections.
- Are currently being designed and shall be installed on a BP field.
ClampOn CEM

Corrosion-Erosion Monitor

- 3 Models alternatives for CEM -

- CEM for ROV installation

- CEM under insulation/coating

- CEM w/mechanical cover
Fully ROV CEM Subsea configurations

- Pre installed
- ROV installed
- Fully interfaced
- Battery powered
- Internal data storage
- Wireless communication
CEM System in the field
• Transducers Clamp with up to 4 transducers.

• Main Clamp with CEM electronic and optional battery
  - 2 transducer clamps can be fitted to 1 Main Clamp.

  – Cost impacts:
    - Material
    - Number of transducers and Clamps/location
    - Connector type
    - Engineering work
    - Pipe Size and location
    - Battery type and size
    - Option Protection cover for falling objects
- Acoustic communication link to surface.
ClampOn CEM

Corrosion-Erosion Monitor

- 3 Models alternatives for CEM -

- CEM for ROV installation

- CEM under insulation/coating

- CEM w/mechanical cover
CEM system solution

Transducers located under coating
Interface - Jumper – hose
CEM under insulation/coating

90 Degree bend – 6,625”

- Transducers under Novolastic – (Transparent)
- 6 Dry Contact transducers
- Coverage – approx 50% Bend area
- 2 x 12 Pin Wet Bulkhead connectors
- Connectors on top of split box.
- Electronic canister have to be located max 7 meter from connectors.
CEM under insulation/coating

90 Degree bend – 6,625” – Coverage.

Coverage area

Coverage – approx 50% Bend area
Coverage of pipe max 35%

6 signal path

Minimum signal path length 400mm

On the inside of the bend we will apply an acoustic damping material to allow max path combinations. Thickness is approx 10mm
The CEM Insulation System

- 4 Transducer under insulation – wired back to a split box
- Each split box can handle up to 4 transducers – 12 pin ROV connector
- Funnel
- CEM Electronic located close to transducers within 7 meters.

- Cost impacts:
  - Material
  - Connector type
  - Engineering work
  - Option Protection cover for falling objects
ClampOn CEM

*Corrosion-Erosion Monitor*

- 3 Models alternatives for CEM -

- CEM for ROV installation

- CEM under insulation/coating

- CEM w/Mechanical cover
CEM installation Subsea

Pipe – 10”

Transducers under mechanical cover

4 or 8 Dry Contact transducers

Coverage – deepening on number of transducers

1 or 2 x 12 Pin
Wet Bulkhead connectors
CEM installation Subsea

Pipe – 10"

- Transducers under mechanical cover – (Transparent)
- 4 Dry Contact transducers
- 12 Pin Wet Bulkhead connectors
- CEM Electronic canister have to be located max 7 meter from connectors.
- Canister ROV mountable
## Coverage - CEM installation Subsea

<table>
<thead>
<tr>
<th>N.B.</th>
<th>O.D. (mm)</th>
<th>WT (mm)</th>
<th>CA (mm)</th>
<th>Transducer Ring separation (mm)</th>
<th>ClampOn CEM coverage (whole circumference of the pipe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8&quot;</td>
<td>219,1</td>
<td>12,7</td>
<td>3</td>
<td>840</td>
<td>70%</td>
</tr>
<tr>
<td>10&quot;</td>
<td>273,1</td>
<td>14,3</td>
<td>3</td>
<td>380</td>
<td>67%</td>
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<tr>
<td>14&quot;</td>
<td>355,6</td>
<td>19,1</td>
<td>3</td>
<td>540</td>
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</tr>
<tr>
<td>16&quot;</td>
<td>406,4</td>
<td>20,6</td>
<td>3</td>
<td>590</td>
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<tr>
<td>18&quot;</td>
<td>457,0</td>
<td>22,2</td>
<td>3</td>
<td>635</td>
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<tr>
<td>20&quot;</td>
<td>508,0</td>
<td>23,8</td>
<td>3</td>
<td>725</td>
<td>84%</td>
</tr>
<tr>
<td>24&quot;</td>
<td>610,0</td>
<td>28,6</td>
<td>3</td>
<td>825</td>
<td>83%</td>
</tr>
</tbody>
</table>
- 4 Transducer under cover – wired back to a split box – then to a 12 pin ROV connector

- Protection Covers and funnels

- CEM Electronic located close to transducers within 7 meters.

  - Cost impacts:
    - Material type
    - Pipe size
    - Connector type
    - Installation method...
    - Engineering work
    - Option Protection cover for falling objects
Subsea CEM Technical data

- **Pipe outer diameter (OD):** min 4” (100 mm)
- **Pipe wall thickness:** 2 mm to 35 mm
- **Distance between transducers:** 0.15 m – 2 m (78” typical)
- **Temperature:** -40 to 180 °C (-40 to 356 °F)
- **Frequency range:** 30 to 300 kHz
- **Sensitivity:** better than 1% of the pipe wall thickness
- **Repeatability:** ±0.04%
- **Power consumption:** Avg 6 Watt - Max 10 Watt
- **Sleep Mode:** 0,001mA
- **Battery Pack:** 5 years with data point weekly
- **Sensor electronics:** DSP 66-MIPS, A/D con. 24bit, 25-Years
- **Installation:** Vertical & Horizontal
- **Water depth:** 3000 Meters
- **Test pressure:** 345 BarA
Conclusion
Clampon DSP Corrosion-Erosion Monitor

- Excellent correlation between measured and actual average thickness values, for a wide variety of defect types demonstrated with witness from independent observers (Shell, Statoil, BP, Hydro, Saudi Aramco, etc)
- Sensitivity of the CEM to changes in wall thickness demonstrated
- Generic defect, groove and pits were machined and detected
- Extremely high unevenness still gave far better results than initially predicted
- Robust nature of thickness evaluation method illustrated and monitored over a long time
- Temperature, flow is not affecting the Guided Waves
- Dry contact transducers have been developed to increase flexibility and stability of the CEM system
- Subsea System under qualification with a BP and have been demonstrated with ROV installation during SIT
ClampOn High Flexibility

- Non-intrusive, cost-effective installation
- ROV Retrofit
- Designed for down to 3000 meters depth
- Battery pack &/or internal logging
- Multifunctional (Sand, PIG, Vibration, CEM)
- All data processing in Sensor unit
- Communication Solutions
Thank you for your attention!

Any questions?

Geir Instanes,
ClampOn

www.clampon.com