Review of Advanced In-Line Inspection Solutions for Gas Pipelines

Thomas Beuker, Dr. Hubert Lindner, Dr. Stephan Brockhaus
17-November-2010
Introduction

- In-Line Inspection of gas pipelines is more demanding, in particular for extreme (low/high) flow and pressure conditions.
- Compressible nature of the medium gas requires special tool configuration i.e. low friction sealing elements or intelligent bypass valves.
- Some threats are more frequent in gas than in liquid lines, e.g. Stress Corrosion Cracking (SCC) or Top of the Line Corrosion (TOL).
- Absence of liquids require new Ultrasonic Testing methods to characterize crack related threats.
• **Introduction**

• **In-Line Inspection – Run Behavior**
  - Controlling the Inspection Speed
  - Controlling the Tool Dynamics
  - Reduced Pressure and Flow Conditions

• **In-Line Inspection – Pipe Anomalies**
  - Dents and Pipeline Geometry
  - Corrosion
  - Cracking
  - Coating Assessment

• **Conclusion**
Content

• Introduction

• In-Line Inspection – Run Behavior
  Controlling the Inspection Speed
  Controlling the Tool Dynamics
  Reduced Pressure and Flow Conditions

• In-Line Inspection – Pipe Anomalies
  Dents and Pipeline Geometry
  Corrosion
  Cracking
  Coating Assessment

• Conclusion
Controlling the Inspection Speed

- Basic Principle of Speed Control Unit
- Pressure Dependency of Differential Flow thru valve for 26”/30” Tool in 30” Pipeline
Controlling the Inspection Speed

![Diagram showing various components and data points related to the inspection speed.]

- **Launcher**
  - **Gas Velocity**: 8.4 m/s
  - **Gas Flow**: 2,868,458 sm³/h
  - **Pressure**: 6.53 MPa
  - **Temperature**: 40°C
Controlling the Inspection Speed

- ILI Inspection of a 56” Gas-Pipeline
- 1.5D; Mitered Bends
- High Resolution MFL
- Difference between Tool and Flow 5m/s

<table>
<thead>
<tr>
<th></th>
<th>Launcher</th>
<th>Receiver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Velocity</td>
<td>8.8 m/s</td>
<td>10.1 m/s</td>
</tr>
<tr>
<td>Gas Flow</td>
<td>3,060,000 sm³/h</td>
<td>3,060,000 sm³/h</td>
</tr>
<tr>
<td>Pressure</td>
<td>6.68 MPa</td>
<td>5.52 MPa</td>
</tr>
<tr>
<td>Temperature</td>
<td>40°C</td>
<td>27°C</td>
</tr>
</tbody>
</table>
Controlling the Tool Dynamics

- ILI Inspection of a 26” Gas-Pipeline
- Two runs were performed
- Gas Equalization within 50m with Speed Control
Tool Selection Guideline for Low Pressure Gas Lines

- Standard Set Up
- Piggable with minor modifications
- Piggable with major modifications
- Unpiggable

Diagram:
- Low Pressure Kit
- Low Pressure Tools

Legend:
- Standard Set Up
- Piggable with minor modifications
- Piggable with major modifications
- Unpiggable
Low Pressure Kit
- Pull-Unit
- Low Friction Setup
- Wheel Design

Magnet Unit
- Reduction of Friction by 65 %
- Improved Start/Stop

Low Pressure Tool
- Magnet Unit on Wheels
- E-Box Design
- U-Joint Design
Low Pressure Example

Geometry Tool – Standard Setup

- Tool Speed [m/s]
  - 16
  - 12
- Distance [km]

Low Pressure Tool – MFL

- Tool Speed [m/s]
  - 5 m/s
  - 2.5 m/s
- Distance [km]

- OD nom.: 10” (273.1mm)
- Pressure: 16 - 18 bar
- Wall Thickness: 6.35mm – 12.7 mm
- Length: 15km
Low Flow Condition

Special Drive Unit
Just Seal Principle
• Minimum Bypass
• Minimum Friction
• Optimized Centralization
• Optimized Load Capacity
Content

• **Introduction**

• **In-Line Inspection – Run Behavior**
  - Controlling the Inspection Speed
  - Controlling the Tool Dynamics
  - Reduced Pressure and Flow Conditions

• **In-Line Inspection – Pipe Anomalies**
  - Dents and Pipeline Geometry
  - Corrosion
  - Cracking
  - Coating Assessment

• **Conclusion**
Combined ILI-Technologies

- **high resolution geometry** inspection (Geo)
- pipeline route mapping (XYZ)
- **corrosion mapping** with magnetic flux leakage (MFL)
- mapping of **shallow internal corrosion (SIC)** using eddy current technology
Dents and Pipe Geometry

ROSEN Contour Following Proximity Sensor
(Compensated Deflection)

Radius Measurement

\[ \delta = \delta \text{ Touchless Proximity Sensor} + \beta \text{ Electronic Angle Sensor} \]
Dents and Pipe Geometry

Out of Roundness Correlates with Longseam Position

OoR between 0.6mm to 1mm detected
Dents and Pipe Geometry

Accurate Dent Characterization - Combined Technology
Dents and Pipe Geometry

Geometry Tool measurement of check valve.

Checked immediately and approved for MFL run.
NONMANDATORY APPENDIX R
ESTIMATING STRAIN IN DENTS

R1 STRAIN

Strain in dents may be estimated using data from deformation in-line inspection (ILI) tools or from direct measurement of the deformation contour. Direct measurement techniques may consist of any method capable of describing the depth and shape terms needed to estimate strain. The strain estimating techniques may differ depending on the type of data available. Interpolation or other mathematical techniques may be used to develop surface contour information from ILI or direct measurement data. Although a method for estimating strain is described herein, it is not intended to preclude the use of other strain estimating techniques. See also Fig. R1.

R2 ESTIMATING STRAIN

R₀ is the initial pipe surface radius, equal to \( \frac{1}{2} \) the nominal pipe OD. Determine the indented OD surface radius of curvature, \( R₁ \) in a transverse plane through the dent. The dent may only partially flatten the pipe such that the curvature of the pipe surface in the transverse plane is in the same direction as the original surface curvature, in which case \( R₁ \) is a positive quantity. If the dent is re-entrant, meaning the curvature of the pipe surface in the transverse plane is actually reversed, \( R₁ \) is a negative quantity. Determine the radius of curvature, \( R₂ \) in a longitudinal plane through the dent. The term \( R₂ \) as used herein will generally always be a negative quantity. Other dimensional terms are: the wall thickness, \( t \); the dent depth, \( d \); and the dent length, \( L \).

(c) Calculate the bending strain in the circumferential direction as

\[
\varepsilon_c = t \left( \frac{1}{R₀} - \frac{1}{R₁} \right)
\]

(d) Calculate the bending strain in the longitudinal direction as

\[
\varepsilon_l = -\frac{t}{R₂}
\]

(c) Calculate the extensional strain in the longitudinal direction as

\[
\varepsilon_{l} = \left( \frac{1}{2} \right) \left( \frac{d}{L} \right)^2
\]

(d) Calculate the strain on the inside pipe surface as

\[
\varepsilon_i = \left[ \varepsilon_l - \varepsilon_r \right] \left( \varepsilon_1 - \varepsilon_2 \right) \left( \varepsilon_1 + \varepsilon_2 \right)
\]

The outside pipe surface as

\[
\varepsilon_o = \left[ \varepsilon_1 - \varepsilon_2 \right] \left( \varepsilon_1 + \varepsilon_2 \right)
\]

REMARK: Formula not correct
Strain and Stress

\[ \varepsilon = \text{Strain} \quad = \text{displacement} \]
\[ r = \text{radius} \quad = \text{curvature} \]
ILI Geometry Measurement and Analysis
ILI Geometry Measurement and Analysis

Accurate Sampling

\[ r = \infty \]

\[ r = 0 \]
Strain and Stress

ILI Geometry Measurement and Analysis

Accurate Sampling  Spline Approximation  Curvature Determination  Membrane\(^1\) Dent

\(^1\) local membrane strain in dent
Absolute strain

ILI Geometry Measurement and Analysis

Accurate Sampling

Spline Approximation

Curvature Determination

Membrane Dent

Strain Calculation

\[ \varepsilon_{total} = \sqrt{\varepsilon_1^2 - \varepsilon_1\varepsilon_2 + \varepsilon_2^2} \]

Bending strain + membrane strain = total strain
Results and Reporting

Data Arrays
- Strain
- Curvature
- Geometry

Dent Parameter
- Length
- Width
- Depth
- max Strain

Strain Data Visualization

List of Significances
Content

- Introduction

- In-Line Inspection – Run Behavior
  - Controlling the Inspection Speed
  - Controlling the Tool Dynamics
  - Reduced Pressure and Flow Conditions

- In-Line Inspection – Pipe Anomalies
  - Dents and Pipeline Geometry
  - Corrosion
  - Cracking
  - Coating Assessment

- Conclusion
Corrosion Mapping

Corrosion Mapping with MFL

Corrosion Mapping with Shallow Internal Corrosion Sensor
Measurement Principle

**SIC Sensor**

**SIC Sensor (schematic)**

Sensor over full pipewall

Sensor over metal loss

Pipe wall

Amplitude change

Phase movement
Measurement Principle

SIC Sensor

- Sensor over full pipewall
- Sensor over metal loss

Pipe wall

- Amplitude change
- Phase movement

In Air

Metal Loss

Material

Lift-Off

$\omega L$

$R$

$\text{Material}$
SIC Scan of TOL cut-out

Photograph

Laserscan

SIC Data

Contour plot
Content

• Introduction

• In-Line Inspection – Run Behavior
  Controlling the Inspection Speed
  Controlling the Tool Dynamics
  Reduced Pressure and Flow Conditions

• In-Line Inspection – Pipe Anomalies
  Dents and Pipeline Geometry
  Corrosion
  Cracking
  Coating Assessment

• Conclusion
Measurement Principle

EMAT = Electro-Magnetic Acoustic Transducer

Ultrasonic Sound Wave

Ultrasound is generated inside the pipeline itself

No liquid coupling - applicable in gas-pipeline
Key Advantages of High Resolution EMAT Tool

- **Sender**
- **Receiver**
- Transmission Signal
- Coating Disbondment Detection
- Sensitive Pixel
- Crack
- Echo Signal
- Crack Detection
- Receiver
- Transmission Signal
- Coating Disbondment Detection
Crack Detection

MPI - Pattern

EMAT Channels

1
2
3
4
Field Data

Coating Feature in Gas Line:
Localized coating disbondment

Integral of Transmission Signal

Correct identification of coating disbondment
Field Data

Correct identification of different types of coating

Integral of Transmission Signal

Sequence of coating types:

- epoxy coating
- field applied tape wrap
- factory applied tar coating
Conclusion

• Today, basically all **critical anomalies** can be identified and **characterized** by the various inspection technologies also for gas pipelines

• The **combination** of different inspection technologies allows a more throughout assessment of the pipeline integrity

• The operational requirements of an individual pipeline can be addressed to a wide extend. Nowadays former **non-piggable pipelines can be inspected**

• However, **design of vehicles** providing an acceptable environment for the measurement under real operational condition is still posing a **challenge for the future**
Thank You for joining the presentation...