Magnetic Tomography method for inspecting pipelines (MTM)
MTM scanning process

Movement of operator with magnetometer SKIF MBS

Diagrams of SDC (stress-deformed condition)

h = 15 D

Anomaly № 1
Anomaly № 2
Anomaly № 3

Length of anomaly 1
Length of anomaly 2
Length of anomaly 3

Defective section № 1
Defective section № 2
Defective section № 3

Section without defects
Scheme of complex processing MTM data of underground (sub-water) object

1 data flow:
- GPS receiver

2 data flow:
- 1 Unit of MTM detectors
  - X

3 data flow:
- 2 Unit of MTM detectors
  - Y

4 data flow:
- 3 Unit of MTM detectors
  - Z

Unit for analyzing and processing data

- Processing geodesic information
- Processing MTM scanning data

Data base: X, Y, Z, curves of SDC (stress-deformed condition)
SDC diagrams

Object name, direction of inspection – according a product flow

Diagrams of stress-deformed condition (SDC)

Diagrams of general stress

Pipeline situation scheme
MTM data field registration
PRINCIPLE of the METHOD
Non-destructive testing works (NDT) in a pit
MTM data office processing

Section without SDC (stress-deformed condition) anomalies

Sections with anomalies
Physical grounds of the method enabling the development of the magnetic tomography method

- Magnetoelastic hysteresis phenomenon

\[ H \rightarrow \frac{2}{5} \left( 1 + \sigma \right) \\Delta \mu = \frac{1}{8} \mu \sigma \left( \sigma ' \right)^2 \]

- Part of volume with magnetization oriented lengthwise vector \( \mathbf{l}_0 \) and towards it, correspondingly;

- Residual magnetization of magnet in adjusted condition, that is, after multi-repeated imposition of stress;

\[ \gamma = \frac{I_0}{I_s} \]

- Magnetization of saturation;

- Change of magnetoelastic energy when stress is imposed tension \( \sigma \);

- Constant of magnetostriction;

- Average angular coefficient;

- Change of domains magnetostatic energy;

- Demagnetizing index of inclusions (various types of defects of structure);

- Complete piezomagnetic change of magnetization in the first and second volumes, correspondingly;

- Energy of interaction of magnetization with field, essential for interdomain boundaries to get over potential barriers, \( H_k \) – average critical field;

- Is developed owing to detention of domains at energy barriers (defects of array) and also owing to additional magnetization of matrix by inclusions having value of residual magnetization higher than matrix’s.

Ranks of anomalies danger

- **3** - Good
- **2** - Admissible
- **1** - Inadmissible

**CATEGORY OF METAL CONDITION**

- **Monitoring without repair**
- **Scheduled repair**
- **First priority repair**

**RECOMMENDATION ON ENHANCING RELIABILITY**
Calculation of serviceability parameters

Dependence between a pipeline magnetic field density and mechanical stresses
F = -0.6245 \ln(\sigma) + 1.5

Mechanical stresses $\sigma$

Magnetic index $F$, conditional units

Dependence between complex magnetic index $F$ and mechanical stresses in a pipeline
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetic field density in H or Am⁻¹</td>
<td>10⁻⁸</td>
</tr>
<tr>
<td>Range of an object wall thickness</td>
<td>Starting with 2.8 mm</td>
</tr>
<tr>
<td>Limits regarding pipelines diameters D</td>
<td>56 ≤ D ≥ 1420 mm</td>
</tr>
<tr>
<td>Rate of MTM-inspection</td>
<td>2-5 m/s</td>
</tr>
<tr>
<td>Maximum pressure</td>
<td>Not limited</td>
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<tr>
<td>Minimum pressure for gas pipelines</td>
<td>0.02 MPa</td>
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<tr>
<td>Minimum radius of turning (bend)</td>
<td>Not limited</td>
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<tr>
<td>Internal minimum diameter</td>
<td>Not limited</td>
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<tr>
<td>Dimensions</td>
<td>200×200×750 mm</td>
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<tr>
<td>Weight of the tool</td>
<td>4.7 kg</td>
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<tr>
<td>Length of an inspected section, minimum</td>
<td>40 m</td>
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<td>Volume of registration along lengthways an object</td>
<td>100%</td>
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<tr>
<td>Admissible deviation from the axis of an underground object</td>
<td>Not more than 3 D</td>
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<tr>
<td>Admissible distance between the magnetometer and a pipeline (deviation from axis, depth of bedding)</td>
<td>20 D</td>
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<tr>
<td>Step of scanning (registration and data recording by detectors), maximum</td>
<td>0.25 m</td>
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<tr>
<td>Error in determining longitudinal coordinate of anomaly</td>
<td>± 1.5 m</td>
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<tr>
<td>Error in determining angular coordinate of anomaly</td>
<td>20°</td>
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</table>
## MTM Report

### Register of revealed MTM anomalies

<table>
<thead>
<tr>
<th>Coordinates of anomaly, m</th>
<th>Type of fixation</th>
<th>Metal condition: good (3); admissible (2); inadmissible (1)</th>
<th>Integral index $F$, conditional units</th>
<th>Coordinates of anomaly, longitude</th>
<th>Prognosis of anomaly type</th>
<th>Beginning, end, Length of anomaly</th>
<th>Distance from the preceding fixation (-) to the next fixation (+)</th>
<th>Safe operating pressure, MPa, $Tsaf$</th>
<th>Notes:</th>
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</thead>
<tbody>
<tr>
<td>№ anomaly</td>
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<td>Coordinates</td>
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<td>GPS-coordinates</td>
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<td>Rank of anomaly</td>
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<td>Types of anomalies:</td>
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</table>

**Types of anomalies:**
- Metal loss
- Crack-like defects
- Geometry change
- Weld joint defects
- SDC (stress-deformed condition) anomalies

**Recommendation on enhancing reliability of a pipeline section**
- Section for the first priority repair (1)
- Section for the scheduled repair (2)
- Section without repair - monitoring (3)
Map-scheme with fixing an object to topo-base (Tierra Del Fuego, Patagonia, Argentina)
Distribution of anomalies lengthways an object
Distribution of angular coordinates of anomalies

Часовое расположение аномалии объекта ООО "ЛУКОЙЛ-Западная Сибирь", ДНС-ЦПС,
1. Situational, geodesic and other schemes, tables describing the MTM results;
2. Data illustrating the methodic of field and office works;
3. Data characterizing principals and peculiarities of revealing SDC anomalies of a ferro-magnetic pipeline;
4. Data relevant to the work results.

1. Maps of distributing parameters of SDC anomalies of an object;
2. Situational Maps-schemes of an object; diagrams
3. Maps of geodesic positioning of an object by GPS-coordinates;
4. Schemes of comparing the inspection data with topo-base of a pipeline route.

Typical structure of data submitted during any Report term