Understanding damage to underground pipelines due to horizontal directional drilling
AS2885 requires explicit understanding of pipeline response to all external interference threats, throughout pipeline life cycle:

- Design
- Integrity Management
- Safety Management Studies
- Land Development Planning around pipelines
Target HDD Rig Sizes for Research:

- Utility installation in residential areas
- Typical pilot holes 60 – 120mm diameter
- Typical utility 60 – 250mm diameter
HDD Equipment – Bit Types

HDD Bit types and Sizes:

• Typical for utility rigs for range of ground conditions
HDD – Pipeline Interaction: Forces

Thrust

Lateral Restraint

Pipe Diameter, WT and Grade

Drill Bit Type and Diameter

Torque

Drill Bit Axial, Rotational Speeds, Duration of Contact

Paper 15: Understanding damage to pipelines due to HDD

6–10 June 2022
HDD – Pipeline Interaction : Damage type

Research considered all potential damage types:

- Gouges
- Puncture
- Drill through
- Denting

Aim to define most credible damage type and failure mode
HDD Experimental Test Rig: Schematic

HDD Test Rig Schematic and Key Components

- Strain Gauge Locations
  Note: Also on vertical pipe support

- HDD Machine
  Rod Torque
  Rod Thrust
  Bearing / Drill Rod Supports

- Soil Box
  Lateral Restraint Flange
  Pipe Movement

- Pipe Support
  Back Restraint
HDD Experimental Test Rig: Test Rig

Phase 1 Test Rig:
• Hydraulic rock drill
  • Max Torque = 400Nm

Phase 2 Test Rig:
• CMS 3020 HDD machine
  • Max Torque = 5000Nm
  • Max Thrust = 150kN
Test conditions related to actual ground conditions through $K_{eq}$, where:

- $K_{eq} = F/\Delta$ at HDD tip
# HDD Experimental Tests: Test Parameters

Total of 130 tests encompassing 40 parameter scenarios:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe Diameter</td>
<td>DN150 to DN500</td>
</tr>
<tr>
<td>Wall Thickness</td>
<td>4.8mm to 12.2mm</td>
</tr>
<tr>
<td>Grade</td>
<td>X42 to X70</td>
</tr>
<tr>
<td>External Coatings</td>
<td>FBE, HDPE, Naprock</td>
</tr>
<tr>
<td>Rotational HDD speed</td>
<td>60 – 180rpm</td>
</tr>
<tr>
<td>Axial HDD speed</td>
<td>5mm/sec</td>
</tr>
<tr>
<td>Initial impact position</td>
<td>0 – 150mm</td>
</tr>
<tr>
<td>Soil Restraint Flange Diameter</td>
<td>200 to 600mm</td>
</tr>
</tbody>
</table>
HDD Experimental Tests: Video

Bearclaw
HDD Experimental Tests : Test Data

Test Data:

- All gouges measured with laser scanner
- Force data for each strike recorded and correlated with gouges
- Compiled database of force-gouge relationships for approx. 600 gouges
HDD Experimental Tests: Observed Damage

2” Steep Taper

Increasing Lateral Resistance

Axis of pipe

4” Bear Claw

5.5” Tricone

Increasing Lateral Resistance
HDD Test Results: Rod Torque and Thrust

Thrust vs Torque

- DN150 2inch
- DN500 2inch (X52)
- DN500 2inch (X70)
- DN150 4inch BC
- DN250 4inch BC 3LPE
- DN250 4inch BC NR
- DN500 4inch Taper
- DN500 4inch BC
- DN500 4inch EC
- DN500 4inch BC (X70)
- DN500 5inch Tricone
HDD Test Results: Lateral Restraint and Plough Force

![Graph showing Plough Force vs Lateral Restraint for different pipeline diameters and materials](image)

- **DN150 2inch**
- **DN500 2inch (X52)**
- **DN500 2inch (X70)**
- **DN150 4inch BC**
- **DN250 4inch BC 3LPE**
- **DN500 4inch BC NR**
- **DN500 4inch Taper**
- **DN500 4inch EC**
- **DN500 4inch BC (X70)**

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**Legend:**
- Red square: DN150 2inch
- Black triangle: DN500 2inch (X52)
- Orange triangle: DN500 2inch (X70)
- Red square: DN150 4inch BC
- Black triangle: DN250 4inch BC 3LPE
- Green square: DN250 4inch BC NR
- Green square: DN500 4inch Taper
- Orange triangle: DN500 4inch EC
- Orange triangle: DN500 4inch BC (X70)
HDD Test Results: Influence on Plough Force

Key Findings 1:

• Strong correlation with Lateral Restraint
• No observable influence from Rotational speed, Pipe OD
HDD Test Results: Influence on Plough Force

Key Findings 2:

- Influenced by Bit Type (i.e. carbide bit vs flat blade).
- Not Bit Size (tip radius)
HDD Test Results: Plough Force and Gouge Depth

Gouge Depth vs Plough Force

- DN150 2inch
- DN500 2inch (X52)
- DN500 2inch (X70)
- DN150 4inch BC
- DN250 4inch BC NR
- DN500 4inch Taper
- DN500 4inch BC (X52)
- DN500 4inch EC
- DN500 4inch BC (X70)
HDD Test Results: Influence on Gouge Depths

Gouge Depth vs Plough Force
Influence of Gouge Position on Pipe (Deg from HDD Axis)

- DN150 4inch BC
- DN250 4inc BC 3LPE
HDD Test Results: Influence on Gouge Depths

Key findings:

- No observed influence from pipe diameter, material grade, coating type.
HDD Test Results: Gouge Depth Relationship

Maximum Gouge Depths All Tests

- Max Depth Data
- Best Fit
- Best Fit + 2SD
HDD Test Results: Gouge Depth Relationship

Max Gouge Depth = 1.3 * ln(PF) – 9.5
HDD Test Results: Gouge Lengths

Gouge length only dependent on bit tip radius
HDD Test Results: Overall Findings

- Observed damage (except Tricone) was series of gouges
  - Max gouge length is dependent on HDD bit tip radius
  - Max gouge depth dependent on number of factors:
    - Lateral restraint i.e. ground restraint, rod diameter
    - HDD bit type
    - Impact position
    - No observed influence from pipe diameter, material grade, coatings, HDD speeds
- Observed damage for Tricone was dimpling
- No associated denting with gouges has been observed
  - However can occur on direct impact with sufficient thrust
- Limitation on capacity of carbide bit tips (approx. 40,000N PF)
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Thank you for your attention.