EPRG-PRCI-APGA

23rd Joint Technical Meeting

Edinburgh, Scotland • 6–10 June 2022

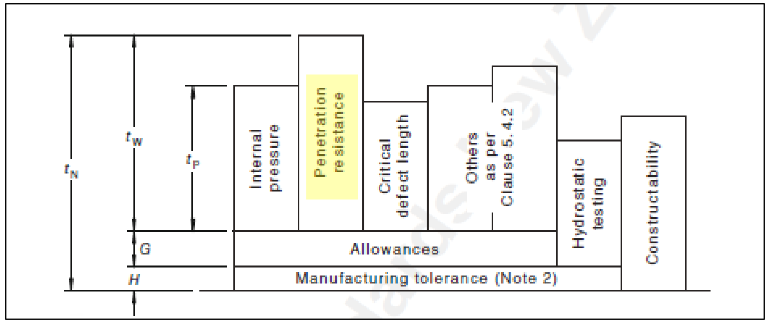
Understanding damage to underground pipelines due to horizontal directional drilling

7 June 2022

Research Motivation

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



(ii) Dimensions of the puncture hole resulting from the maximum identified THREAT, and the resulting failure mode. The failure mode due to penetration may be—

(A) a RUPTURE, if maximum hole length ≥ CRITICAL DEFECT LENGTH;

(B) a leak, if maximum hole length < CRITICAL DEFECT LENGTH; or

(a) *Calculations* For factor B ... values) calculate the excavator size and tooth type(s) to achieve the following:

Penetration.

) Breach of the 'No RUPTURE' requirement [i.e. the smallest machine which can penetrate with a tooth that creates a hole greater than 2/3 of CRITICAL DEFECT LENGTH, so that CDL exceeds 150% of hole length in accordance with Clause 4.9.2(b)].

(iii) RUPTURE (i.e. the smallest machine which can penetrate with a tooth that creates a hole greater than the CRITICAL DEFECT LENGTH).

In all locations, the design shall assess means of limiting the maximum energy release rate through a pipeline segment in the event of a loss of containment in that segment resulting from the largest equivalent DEFECT produced by the THREATS identified in that location.

NOTE: While this Clause is focused on pipe damage by penetration, the usual consequence of an excavator attack is a DENT and GOUGE. DENT-GOUGE combinations work synergistically to significantly lower the pressure at which a pipe fails and therefore can be a particularly dangerous form of damage. While there has been considerable research on the DENT-GOUGE consequence of an excavator attack, it has not developed to a stage where design information can be included in this Standard. Section 11 of this Standard and AS 2885.3 have specific requirements relating to DENT and GOUGE combinations.

(b) The thickness required for resistance to penetration by the design THREAT, if this is used as a method of providing external interference protection in accordance with Clause 5.4. In T1 and T2 LOCATION CLASSES, where thickness is the method chosen to provide penetration resistance, the thickness necessary to provide a minimum level of penetration resistance.

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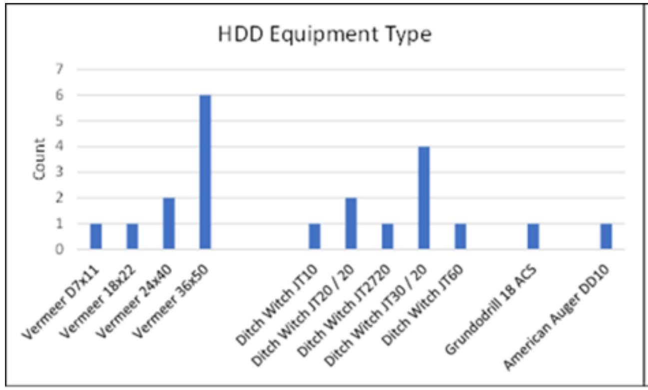
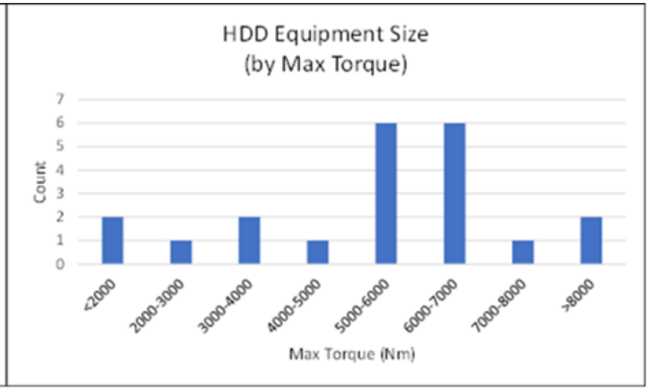
HDD Equipment – Target Rig Sizes

Target HDD Rig Sizes for Research:

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



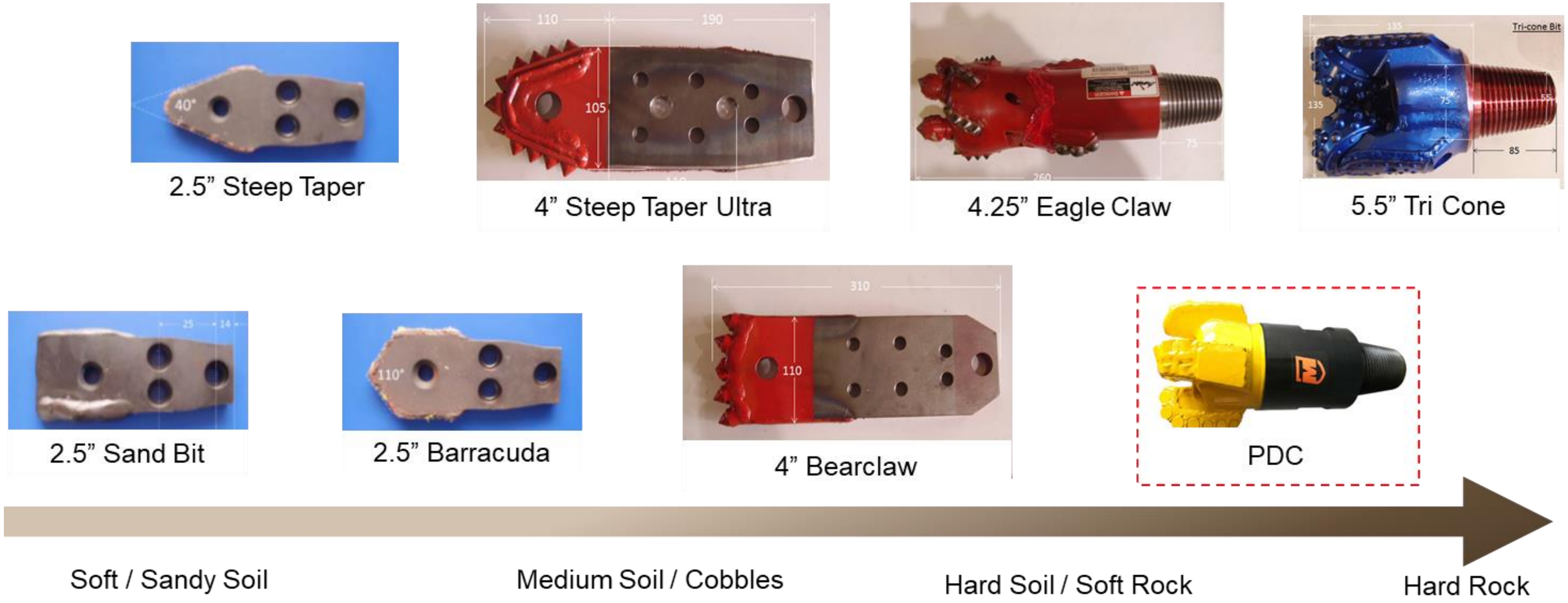


Parameters	HDD Equipment Types	
	Vermeer D36x50	Ditch Witch JT30
Maximum Torque (Nm)	6,700	5,400
Maximum Thrust / Pullback (kN)	160	110 / 130
HDD Rod Diameter (mm)	60 - 67	60

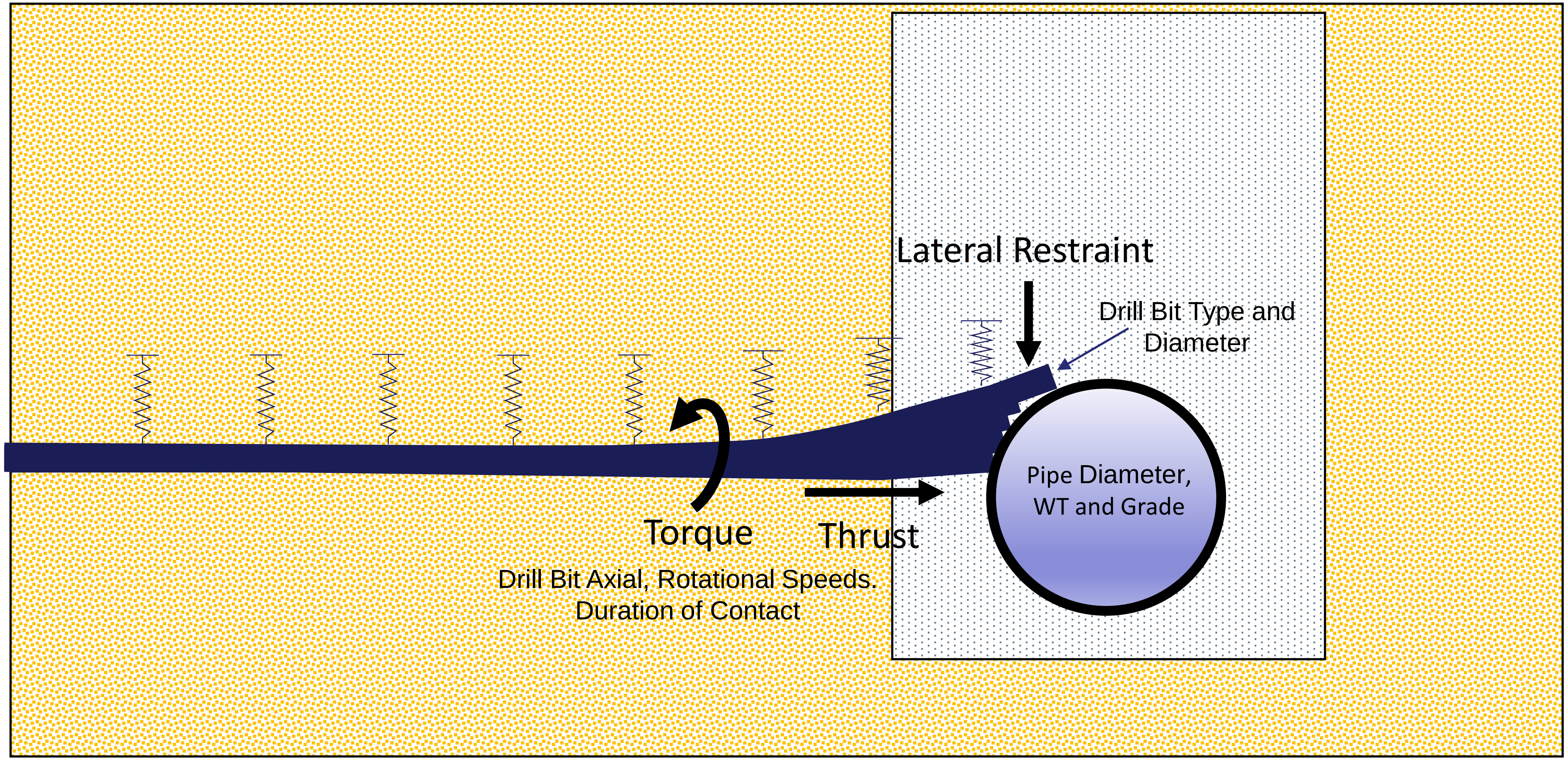
HDD Equipment – Bit Types

HDD Bit types and Sizes:

- Typical for utility rigs for range of ground conditions



HDD – Pipeline Interaction : Forces



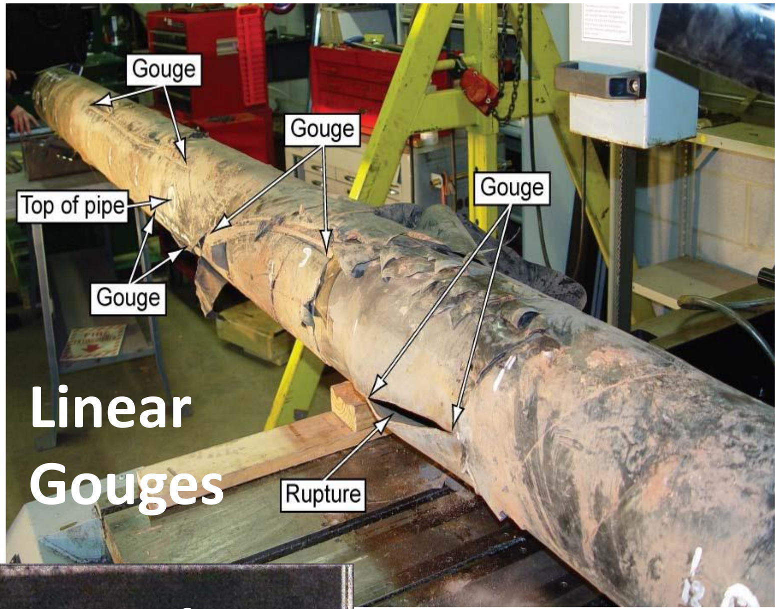
HDD – Pipeline Interaction : Damage type

Research considered all potential damage types :

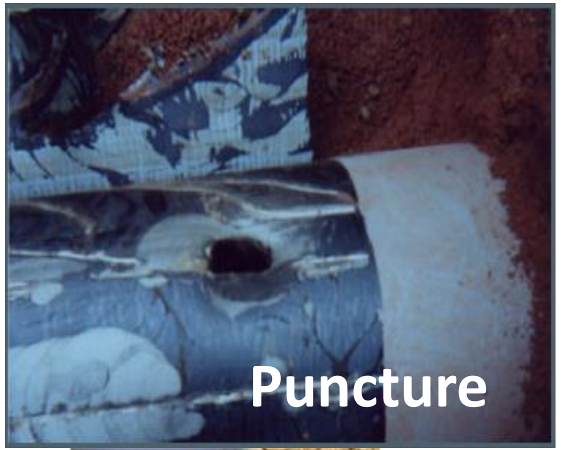
- Gouges
- Puncture
- Drill through
- Denting

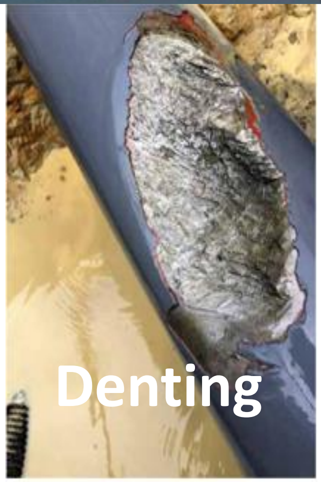
Aim to define most credible damage type and failure mode

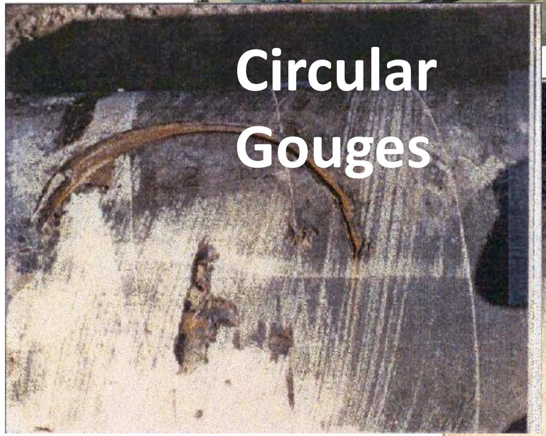
Ref: NTSC/PAB-07/02 2004

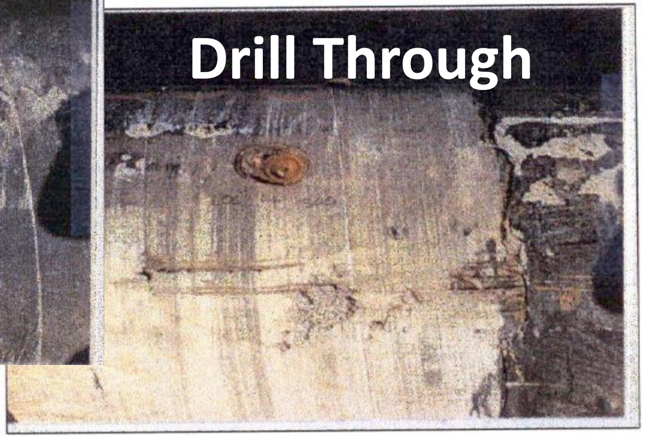


Ref: Brooker 2002





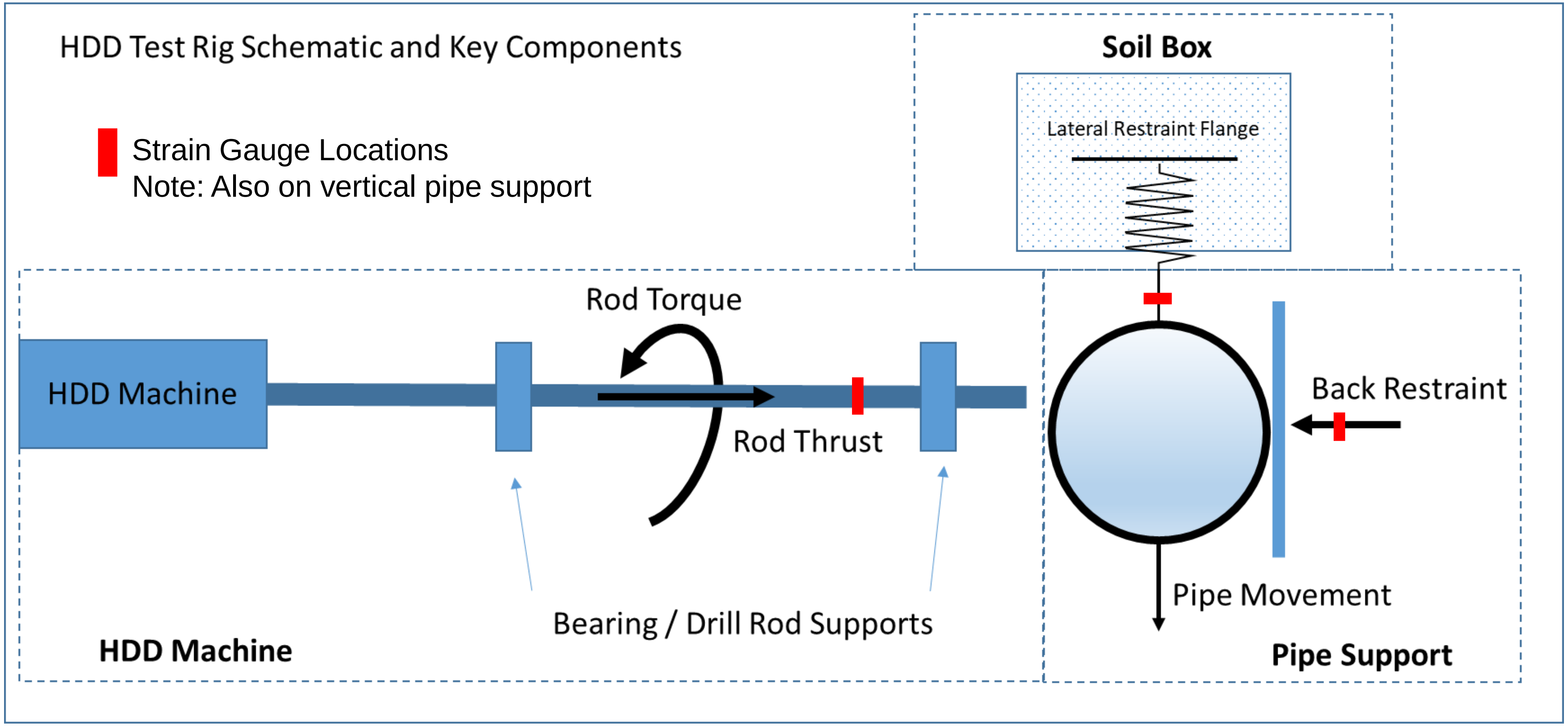




Ref: Tas Gas Network, The Australian Pipeliner 2018

Ref: Gas & Fuel Field Trials 1982

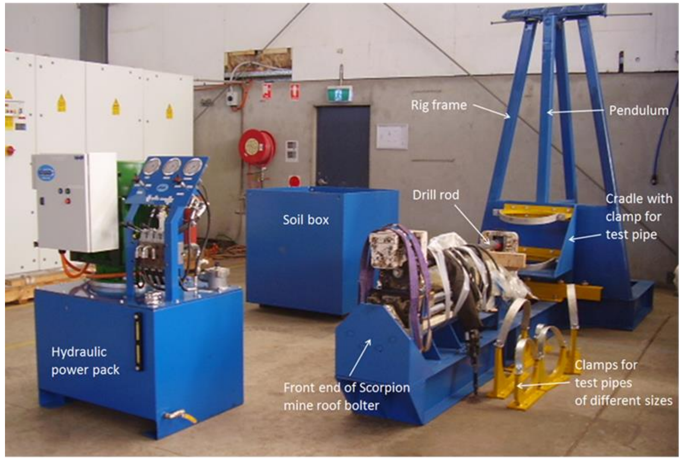
HDD Experimental Test Rig : Schematic



HDD Experimental Test Rig : Test Rig

Phase 1 Test Rig:

- Hydraulic rock drill
  - Max Torque = 400Nm



Phase 2 Test Rig:

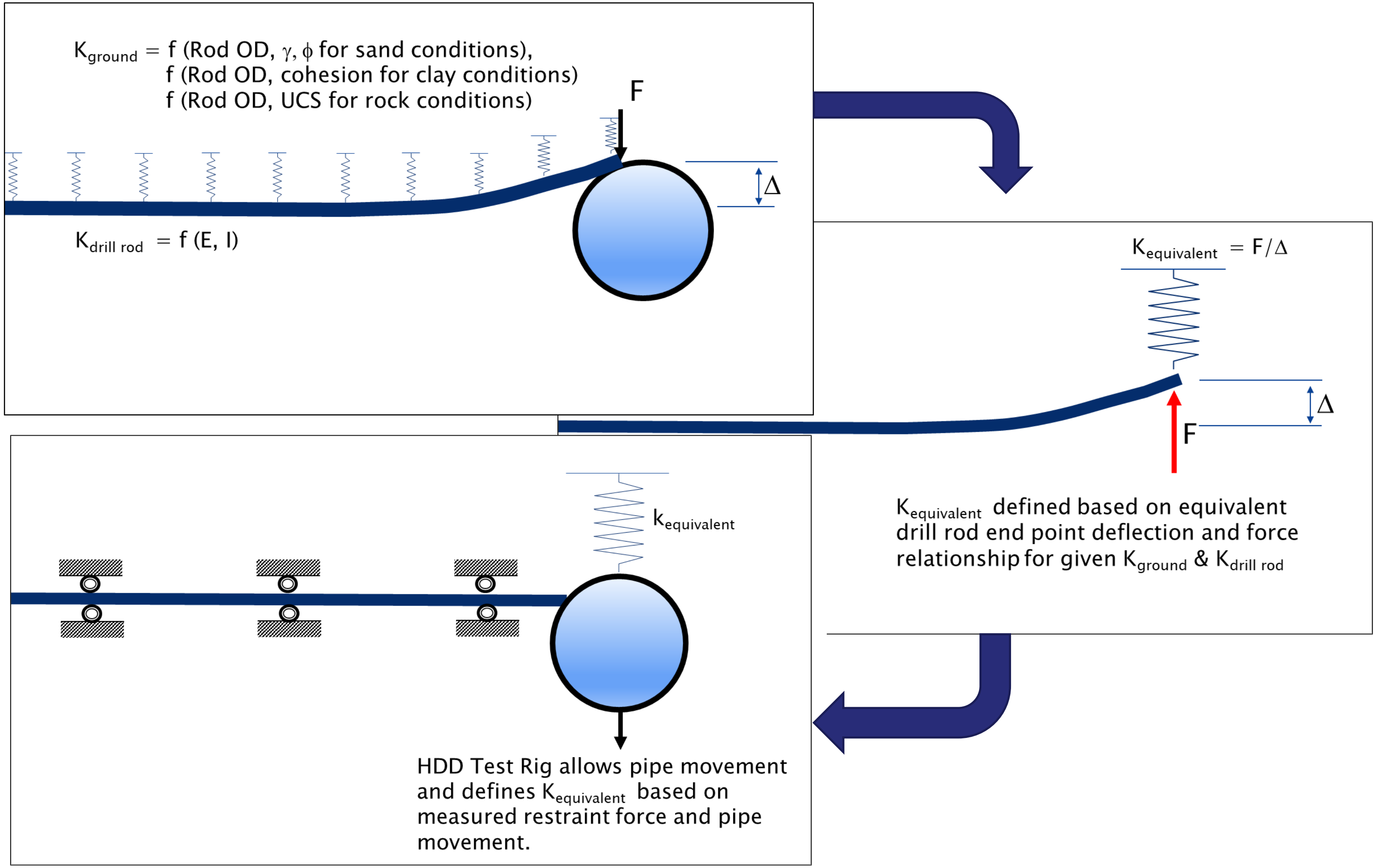
- CMS 3020 HDD machine
  - Max Torque = 5000Nm
  - Max Thrust = 150kN

HDD Experimental Test Rig : Lateral Restaint Modelling

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 :

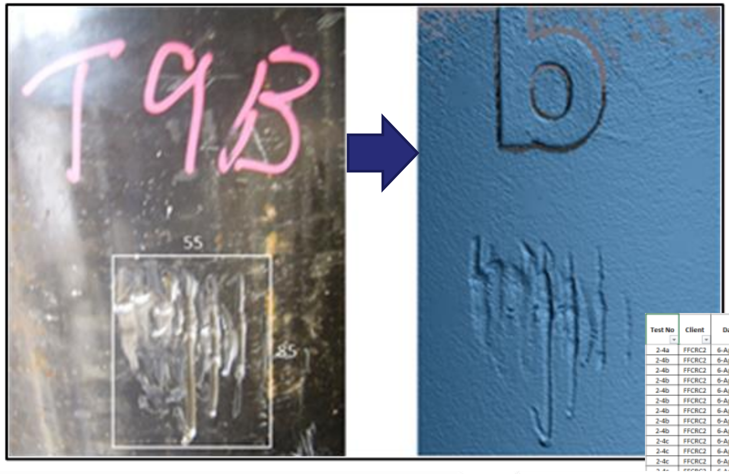
Parameter	Test Range
Pipe Diameter	DN150 to DN500
Wall Thickness	4.8mm to 12.2mm
Grade	X42 to X70
External Coatings	FBE, HDPE, Naprock
Rotational HDD speed	60 – 180rpm
Axial HDD speed	5mm/sec
Initial impact position	0 – 150mm
Soil Restraint Flange Diameter	200 to 600mm

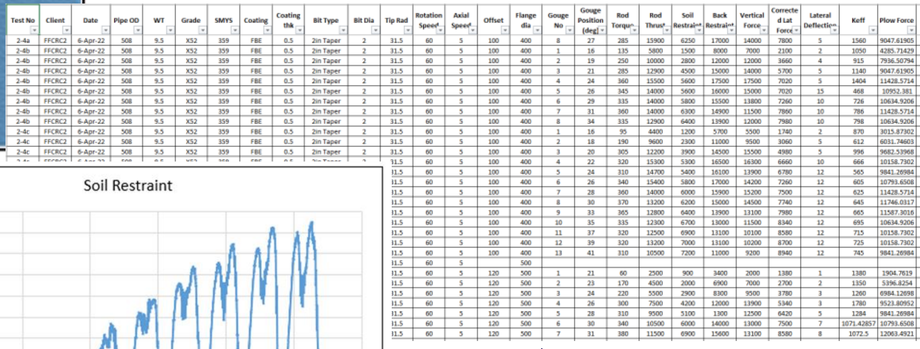
HDD Experimental Tests : Video

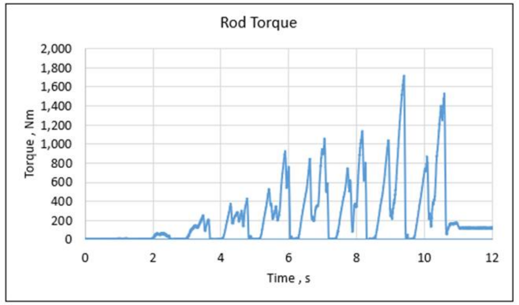
HDD Experimental Tests : Test Data

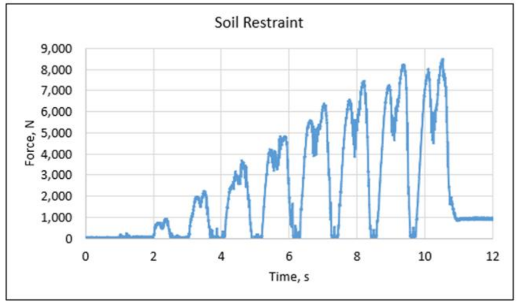
Test Data:

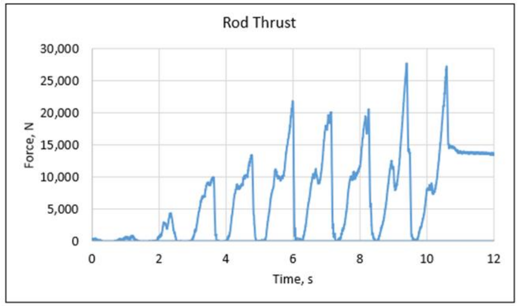
- All gouges measured with laser scanner
- Force data for each strike recorded and correlated with gouges
- Compiled database of force-gouge relationships for approx. 600 gouges

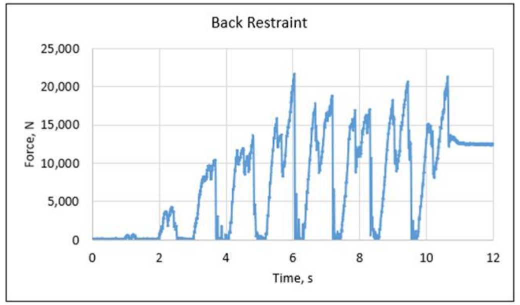




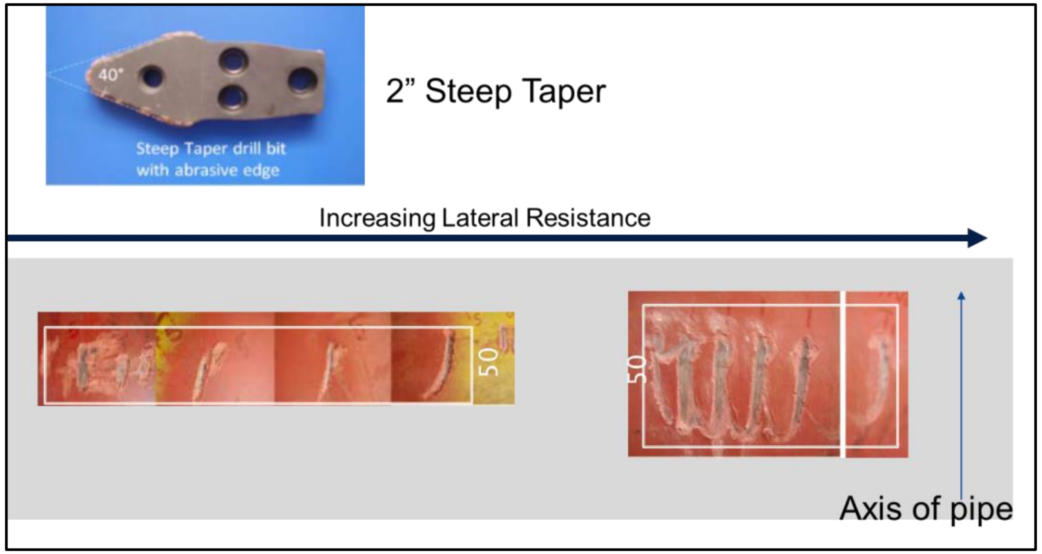


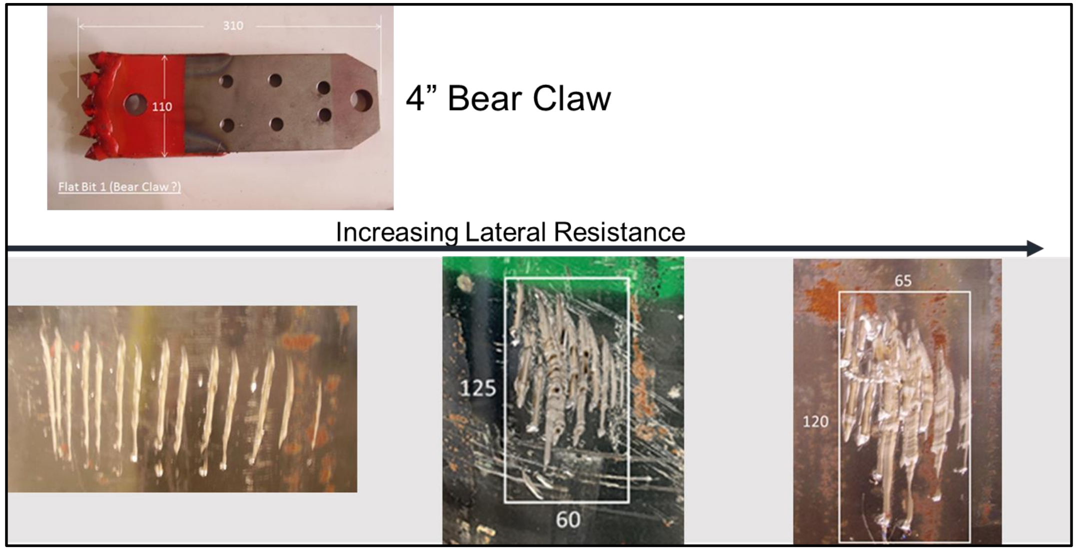


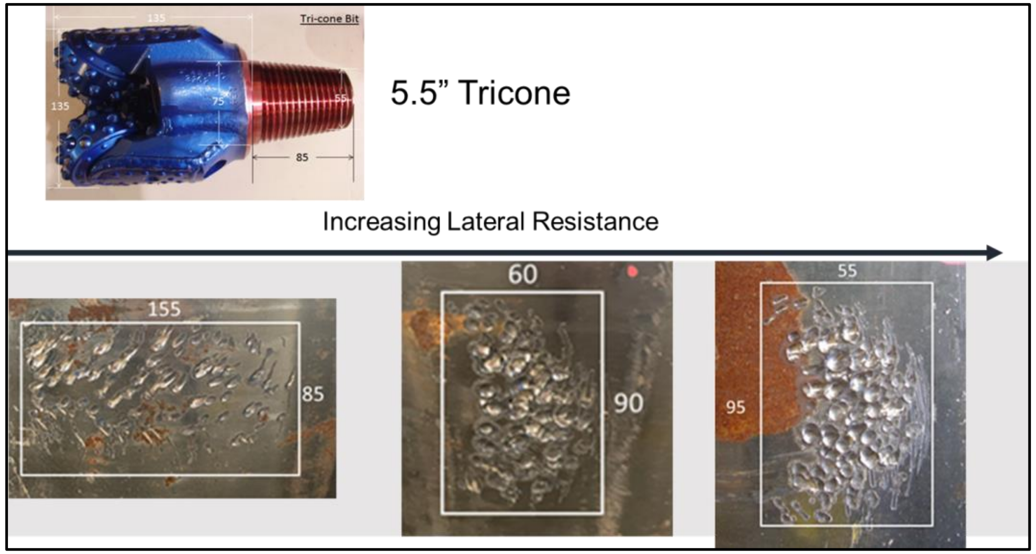




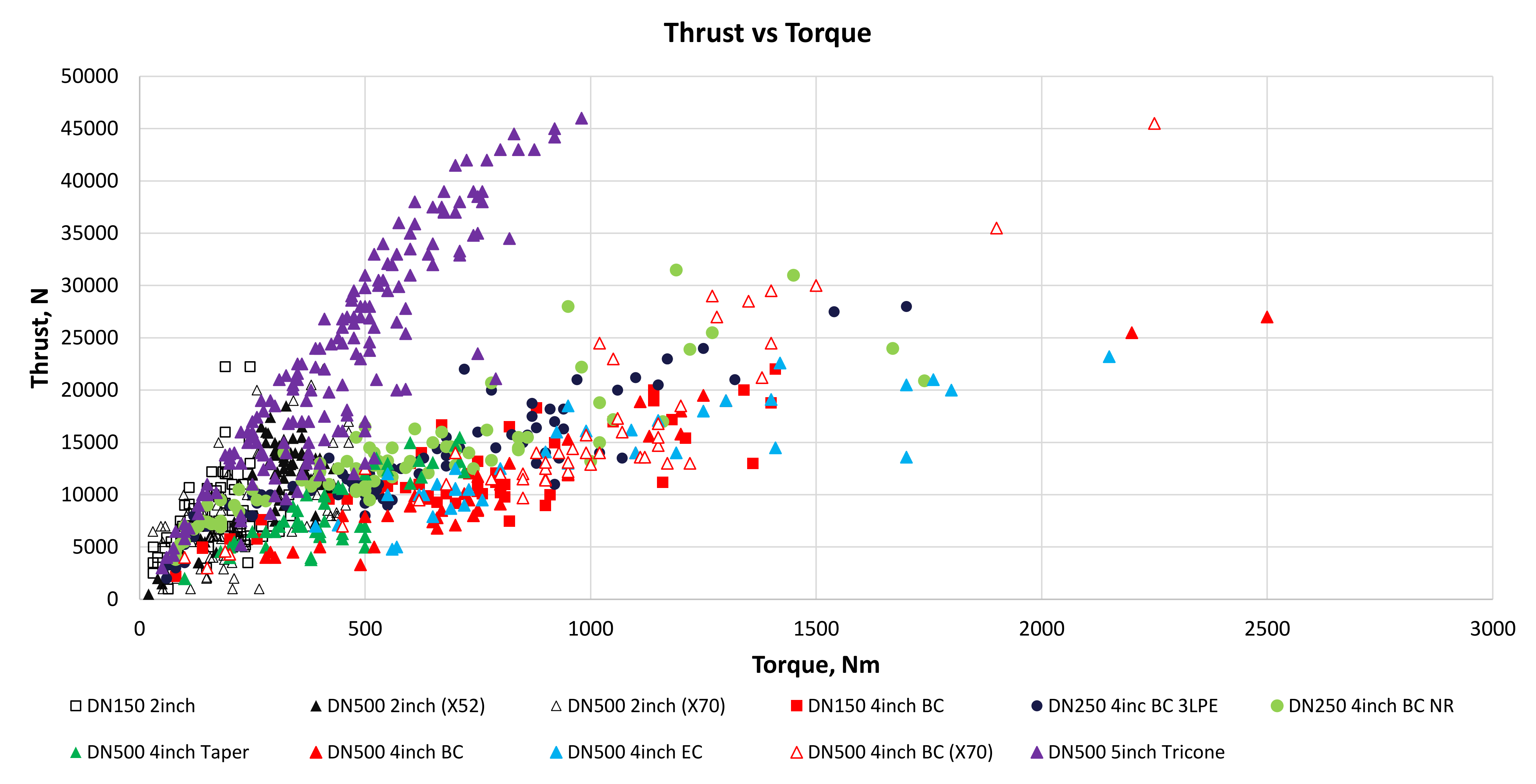
HDD Experimental Tests : Observed Damage



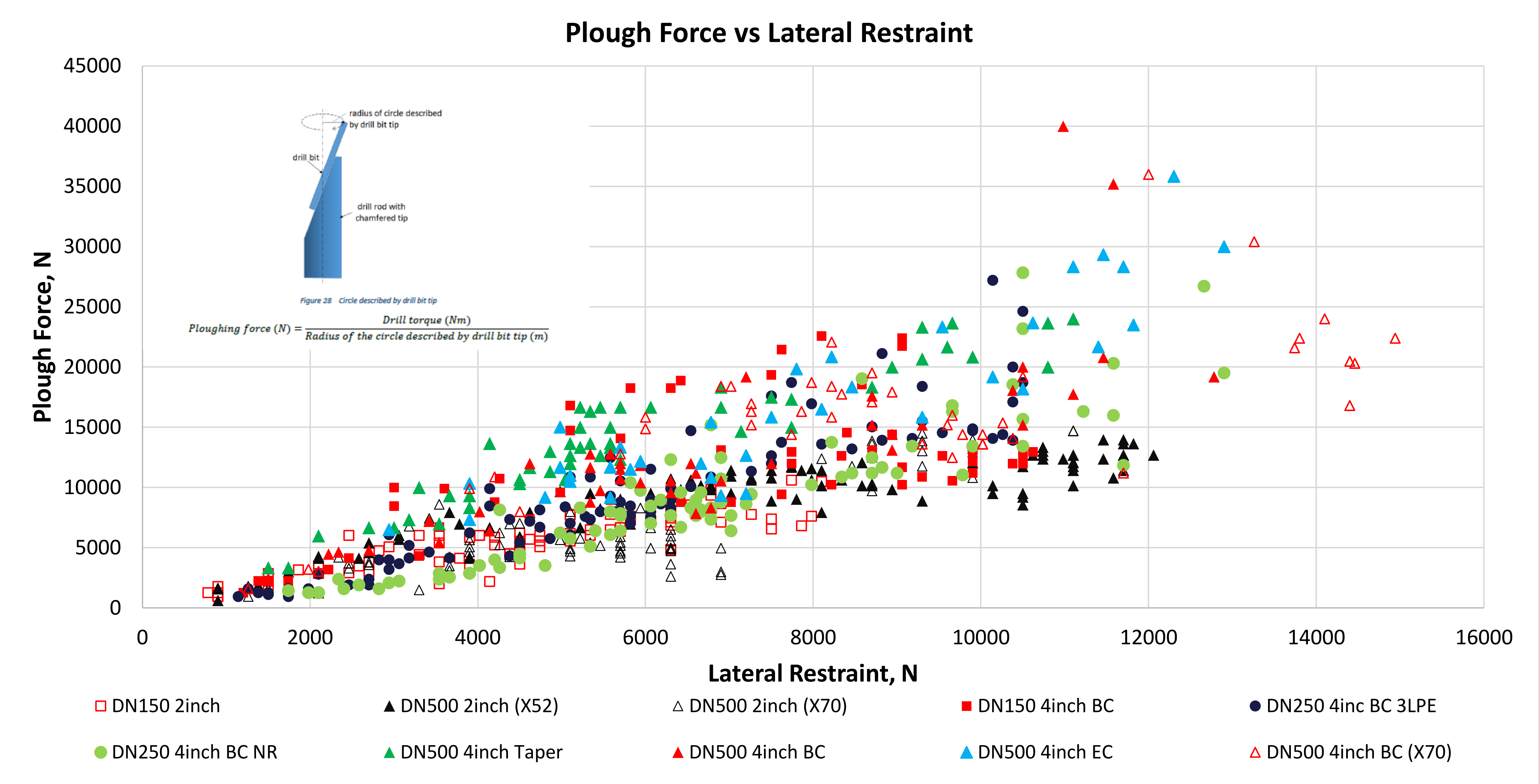




HDD Test Results: Rod Torque and Thrust



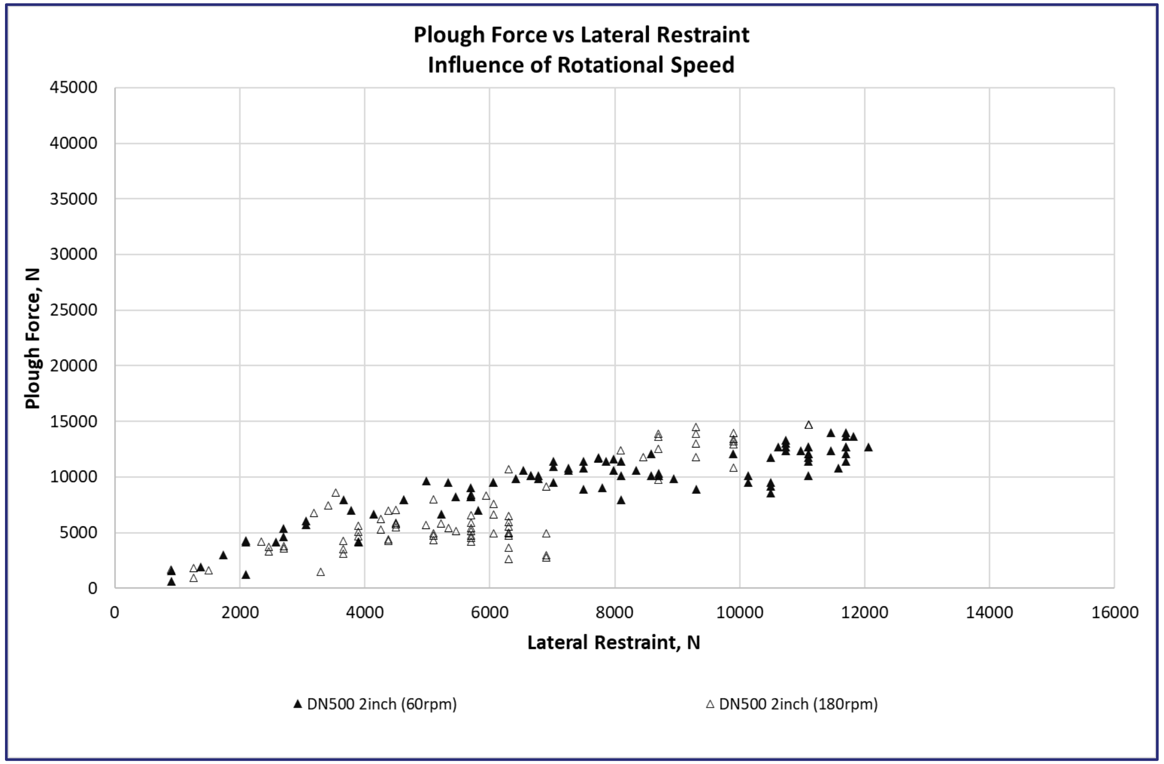
HDD Test Results: Lateral Restraint and Plough Force

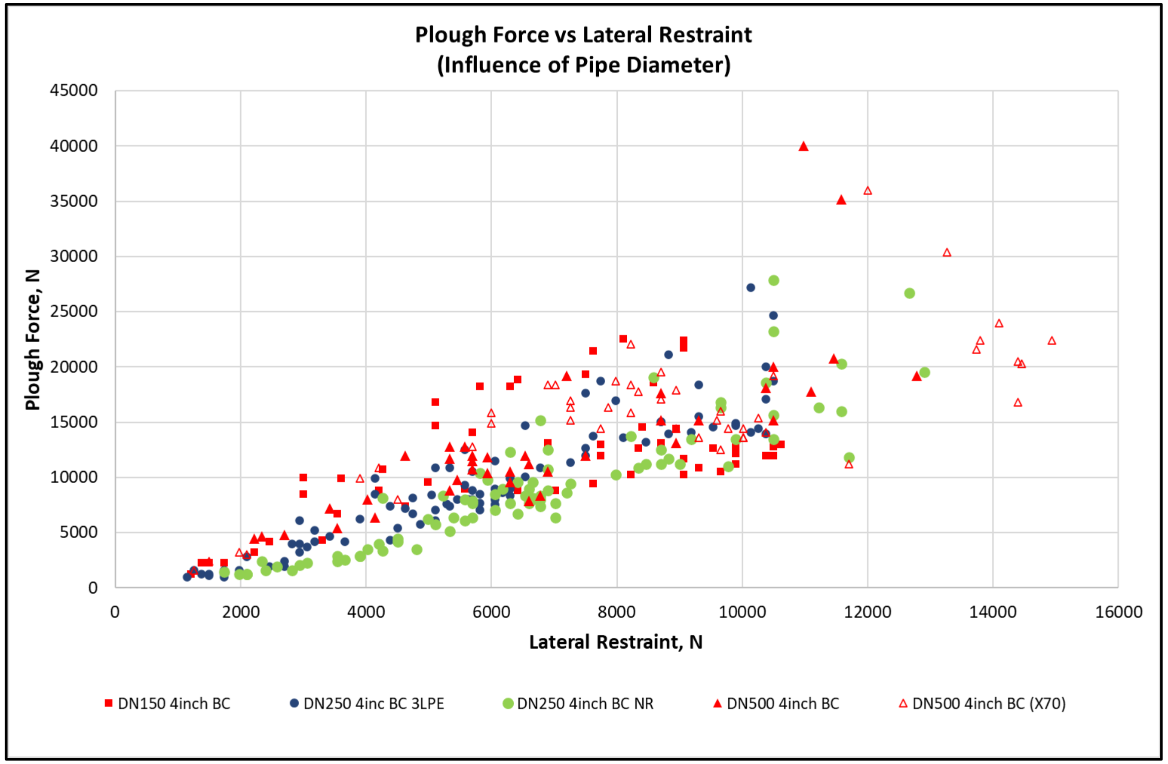


HDD Test Results: Influence on Plough Force

Key Findings 1:

- Strong correlation with Lateral Restraint
- No observable influence from Rotational speed, Pipe OD

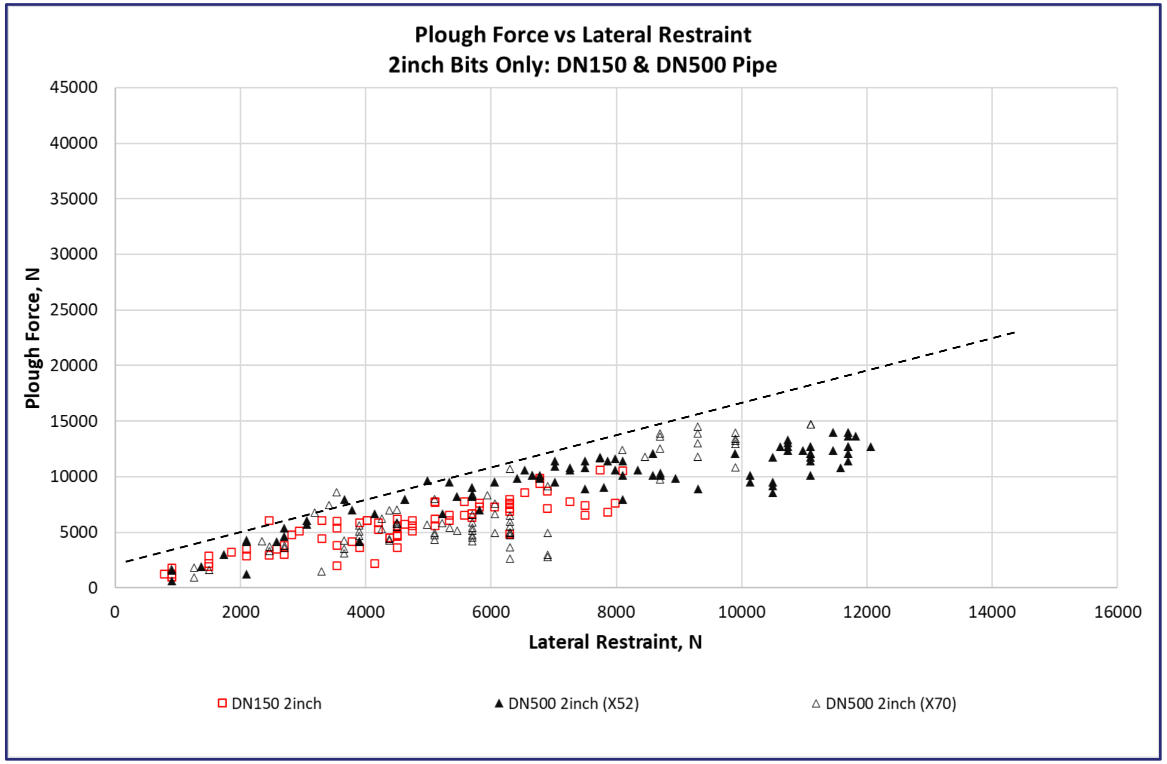


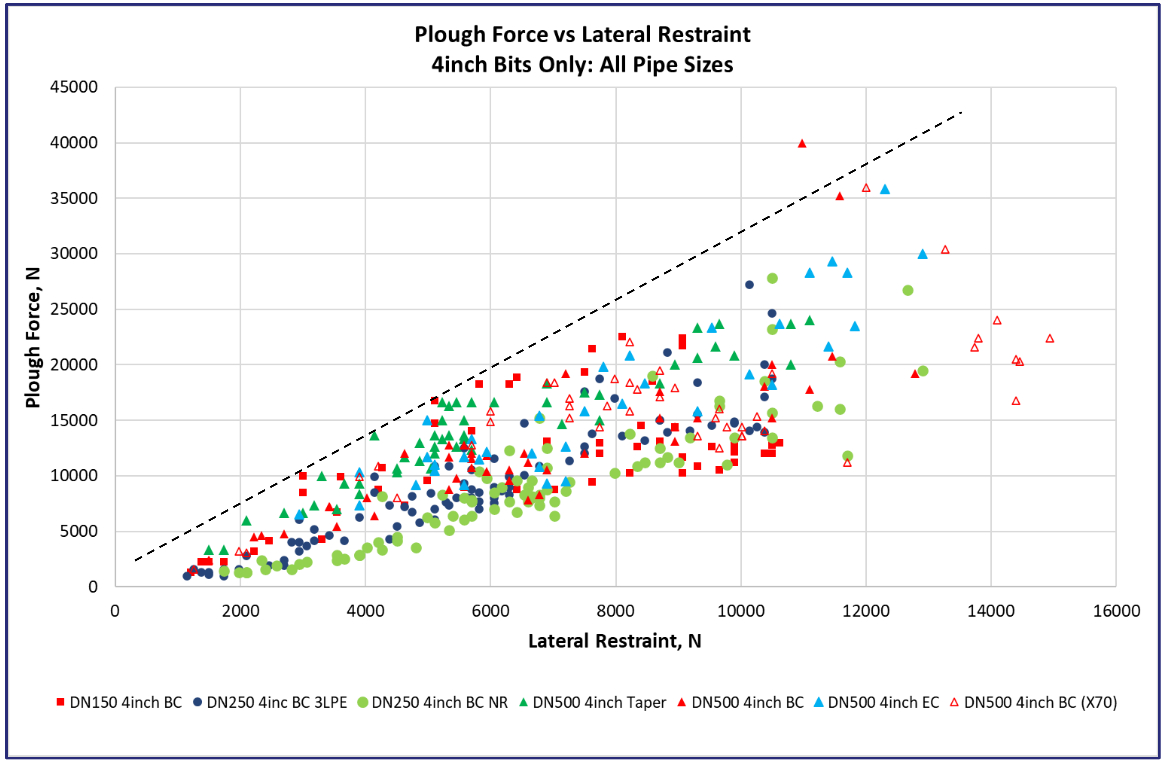


HDD Test Results: Influence on Plough Force

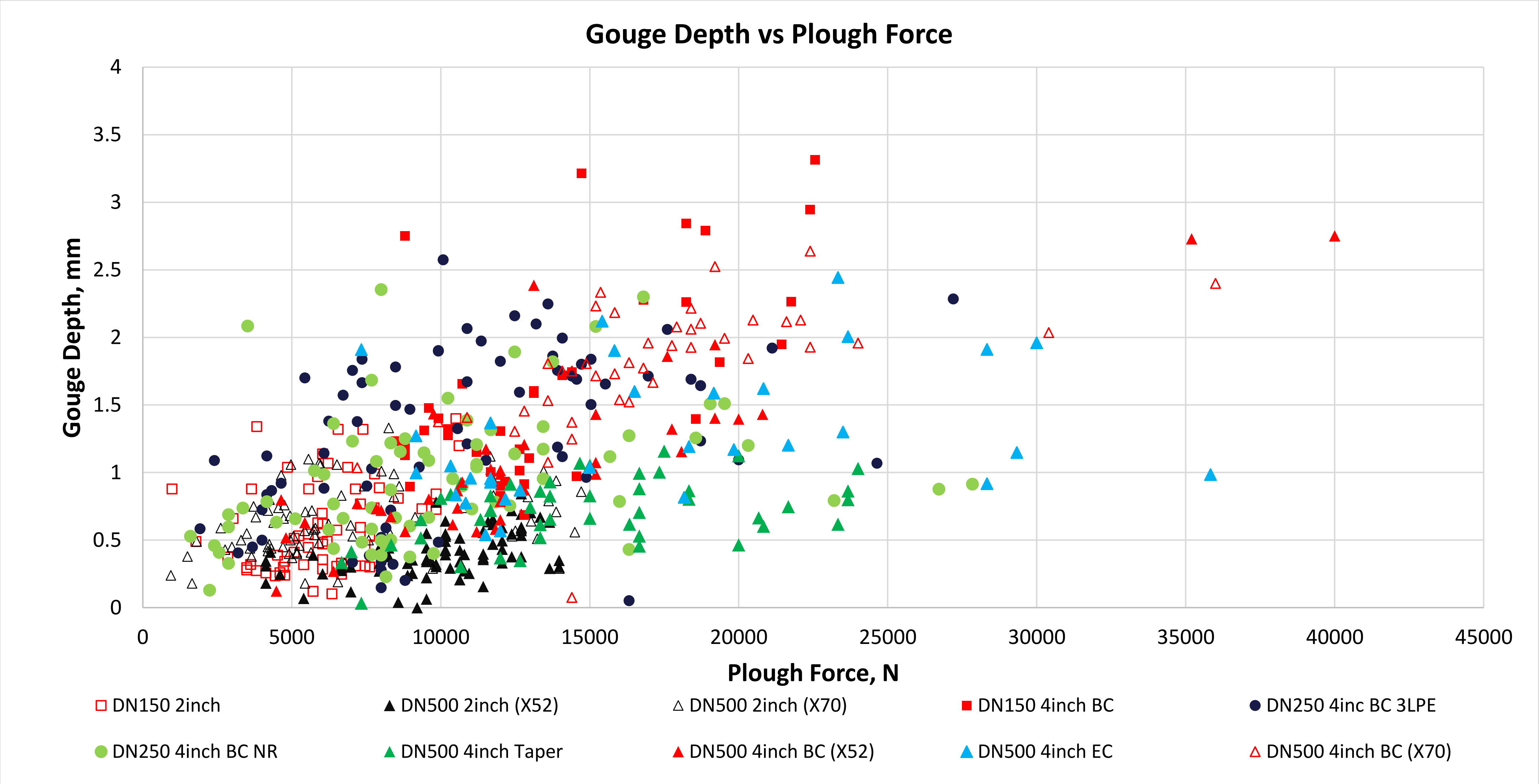
Key Findings 2:

- Influenced by Bit Type (i.e. carbide bit vs flat blade).
- Not Bit Size (tip radius)

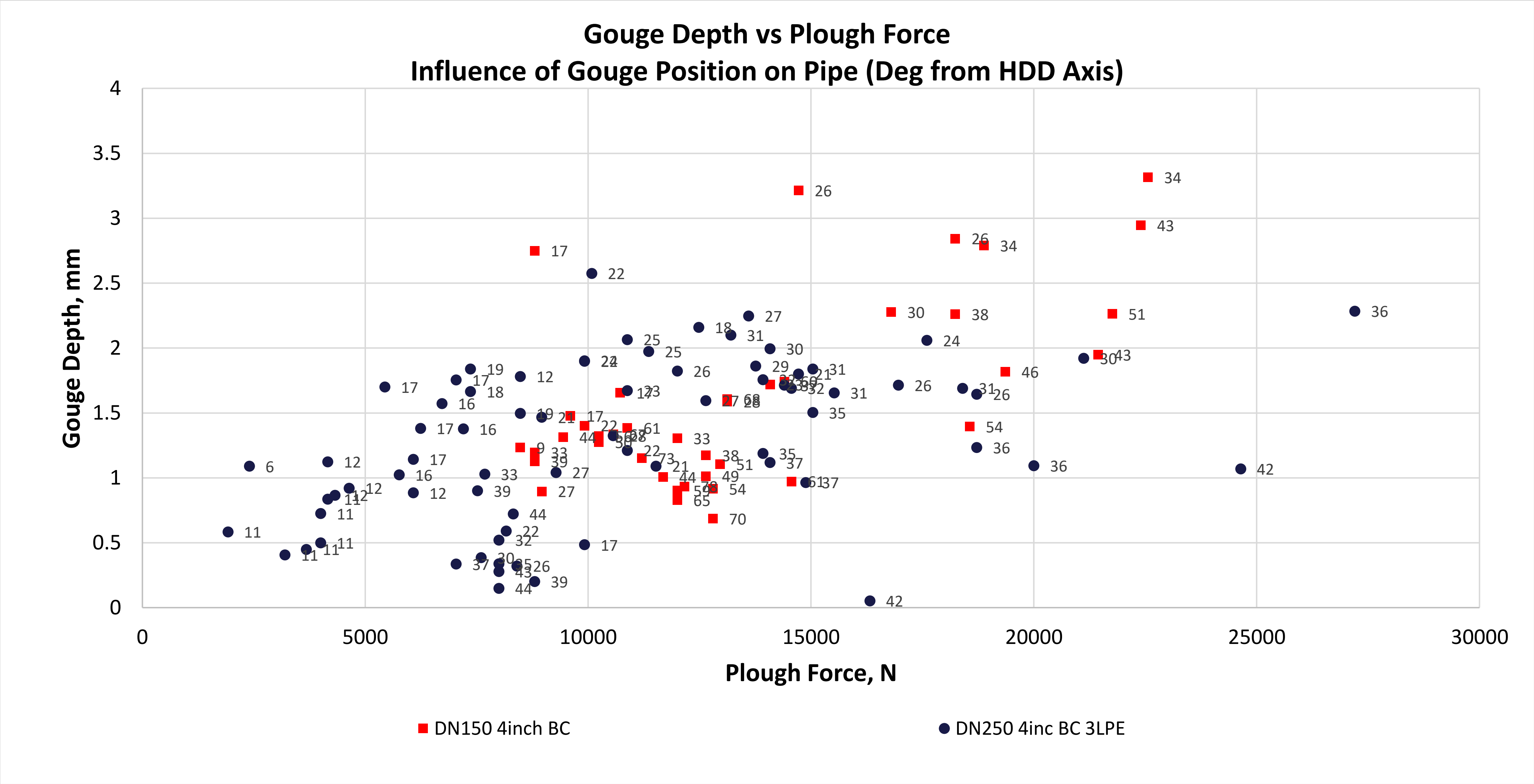




HDD Test Results: Plough Force and Gouge Depth



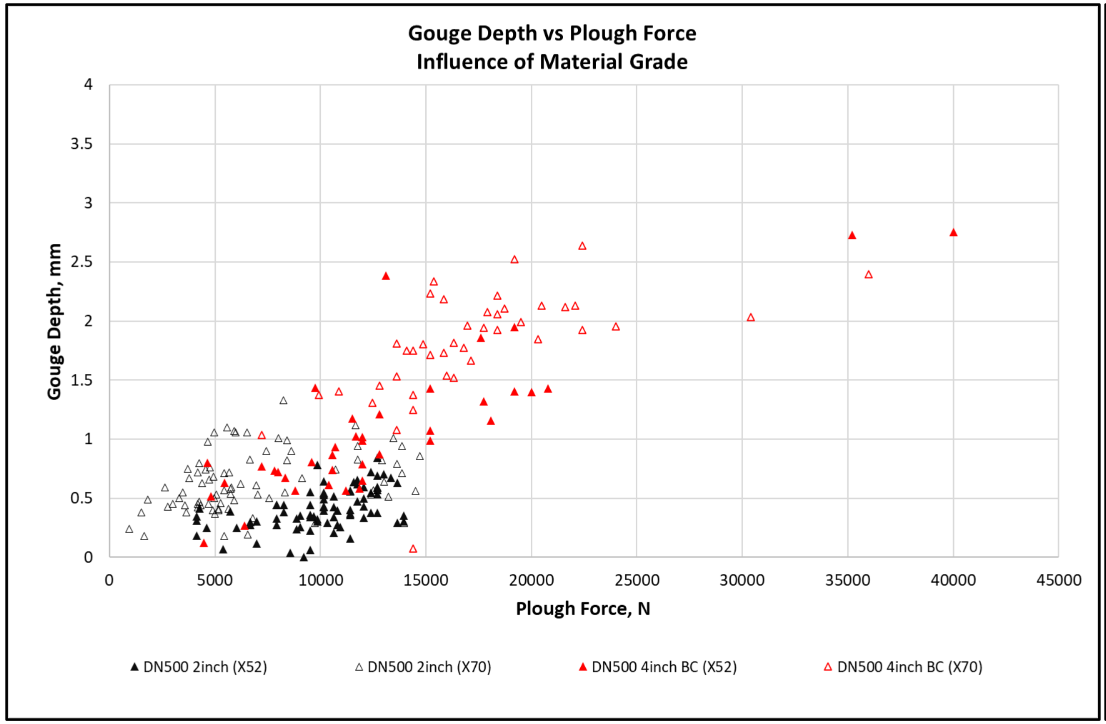
HDD Test Results: Influence on Gouge Depths

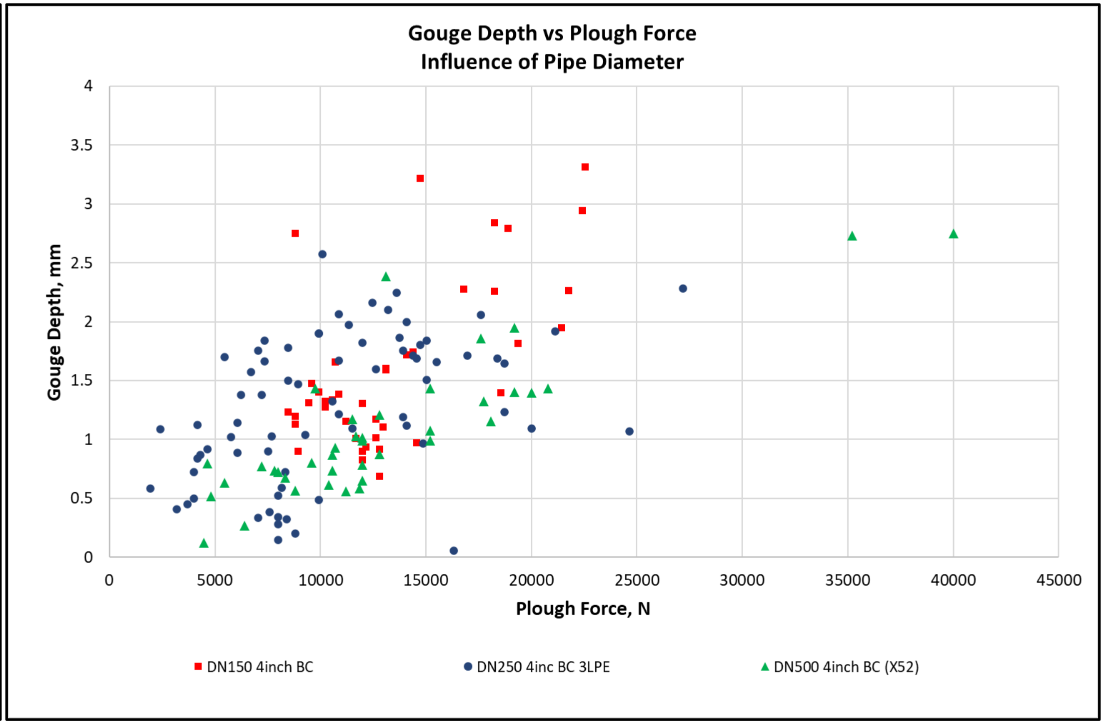


HDD Test Results: Influence on Gouge Depths

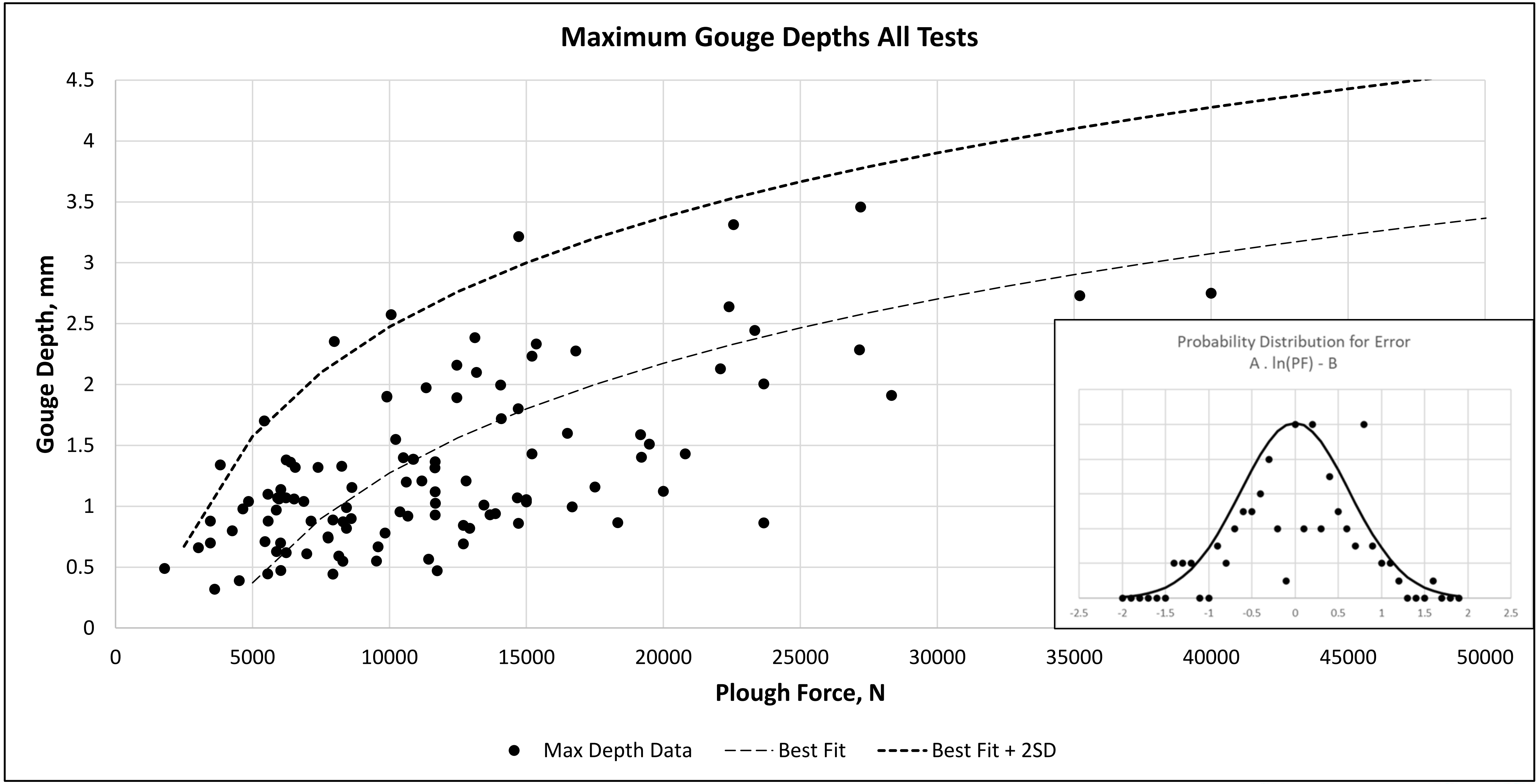
Key findings:

- No observed influence from pipe diameter, material grade, coating type.



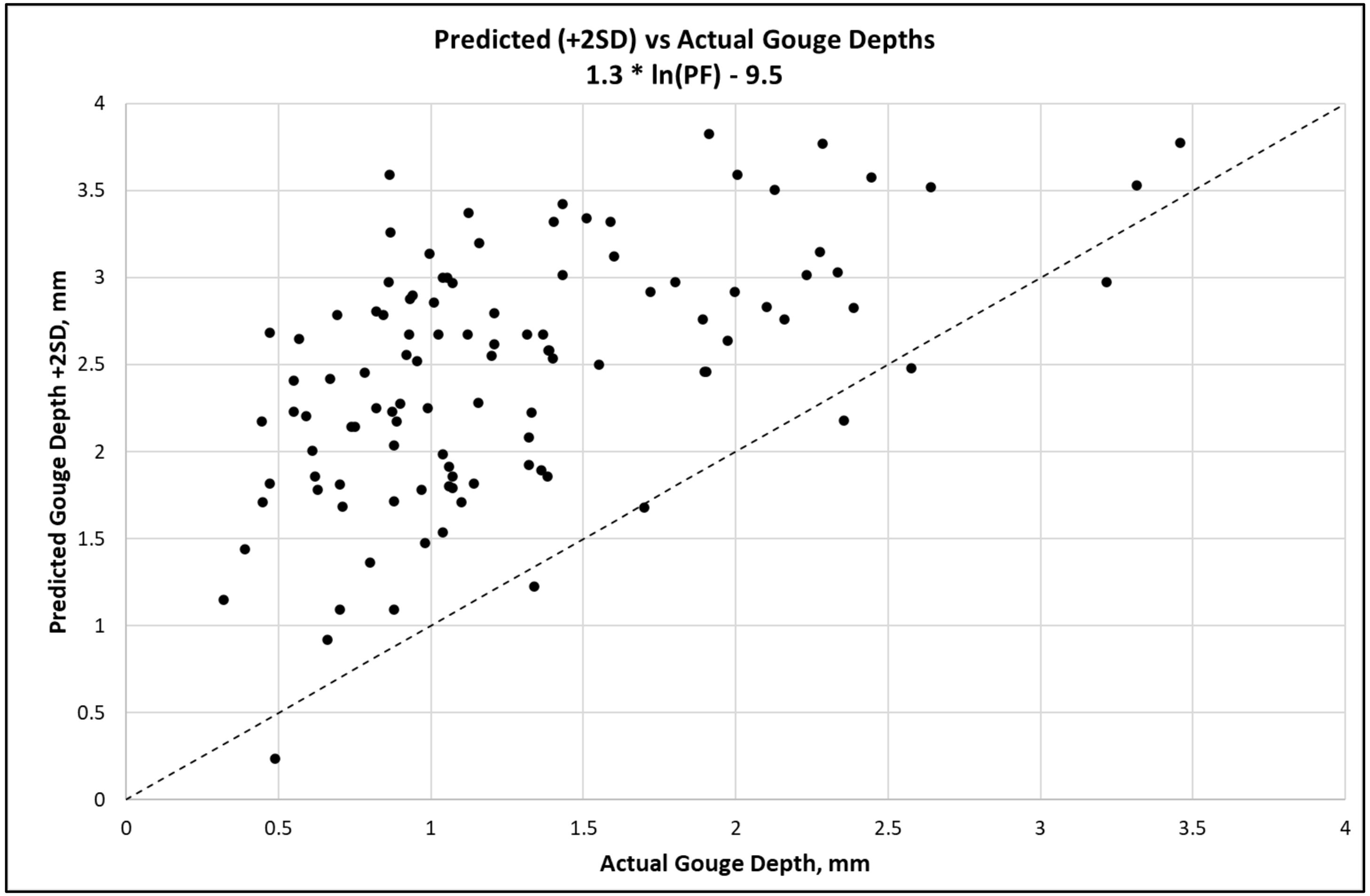


HDD Test Results: Gouge Depth Relationship



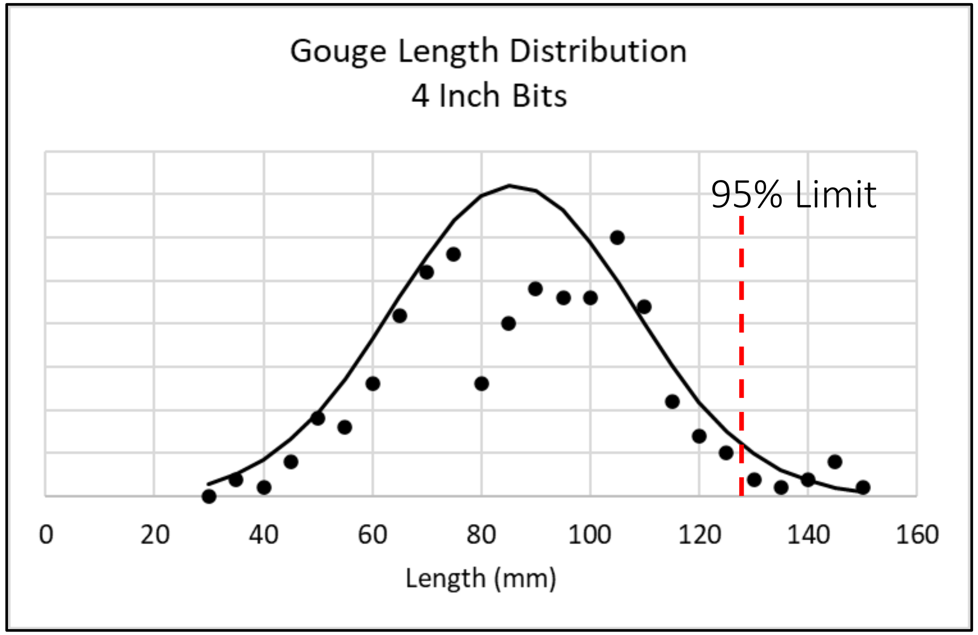
HDD Test Results: Gouge Depth Relationship

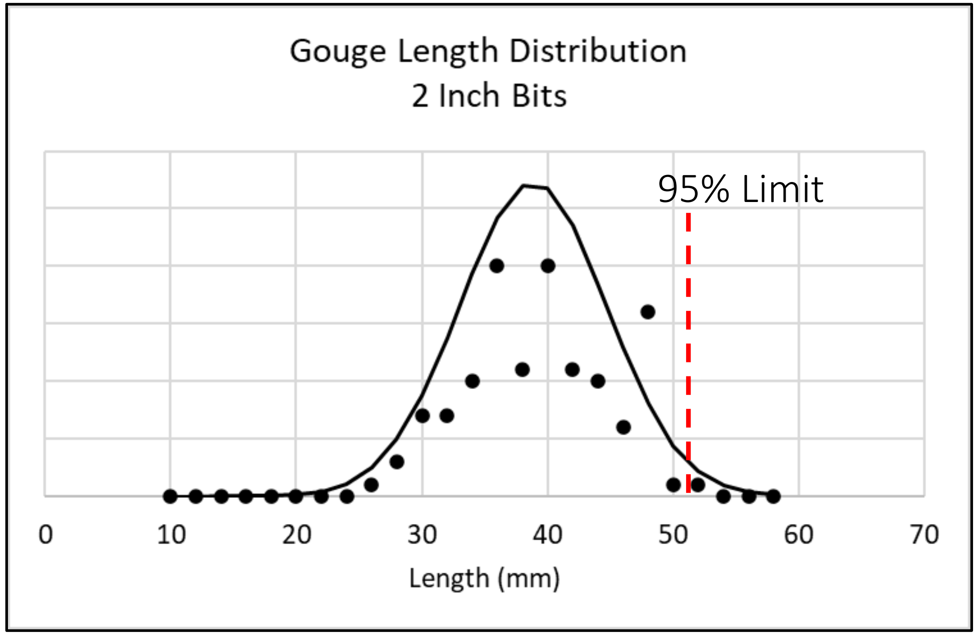
Max Gouge Depth = 1.3 * ln(PF) – 9.5



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)

FUTURE FUELS CRC

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Thank you for your attention.