Reliability of **Drills** and **Drill Stems**

Recent experiences drove our organization to look closely at the key parameters that influence reliability of drill stems.

Further study revealed that there is a complex mix of the following factors which comprise drill and drill stem performance:

- materials specification, condition and selection
- assembly and hardware design and construction
- drivers and driven hardware
- loading and load factors
- environmental conditions
- process and operating parameters

Sources for guidance on this are very limited and rely almost entirely on in-house experience. One would presume that established knowledge from the conventional drilling industry would be front and centre, but it was found that the characteristics and behaviour of coker drilling and cutting makes the problems unique and at the same time widely variable.

Examining all of the above variables and determining their contribution significance was the only path forward to improve the overall performance and reliability.

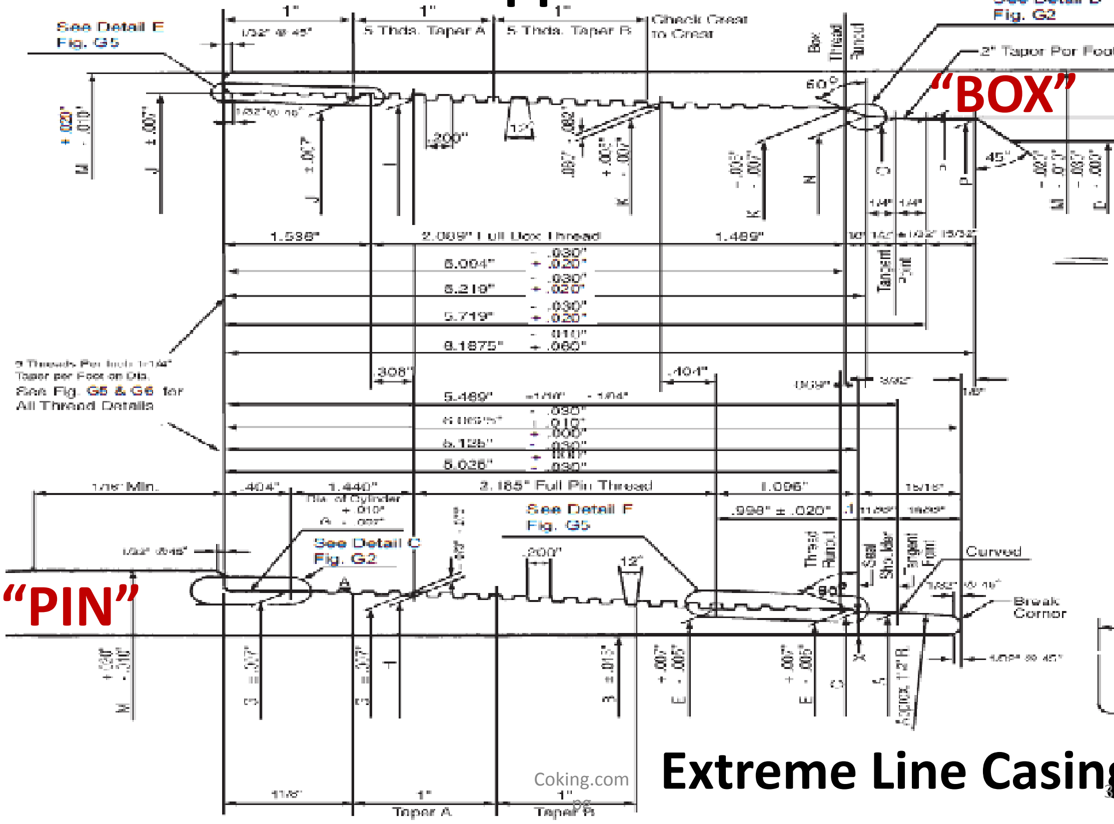
Al Kaye, Reliability - Integrity Engineer

API-5A3 Extreme Line Casing

From STD.API – 5B THREAD Appendix-G

Source Nov.com With permission - NOV Metallurgist

API – 5B THREAD Appendix-G



Extreme Line Casing

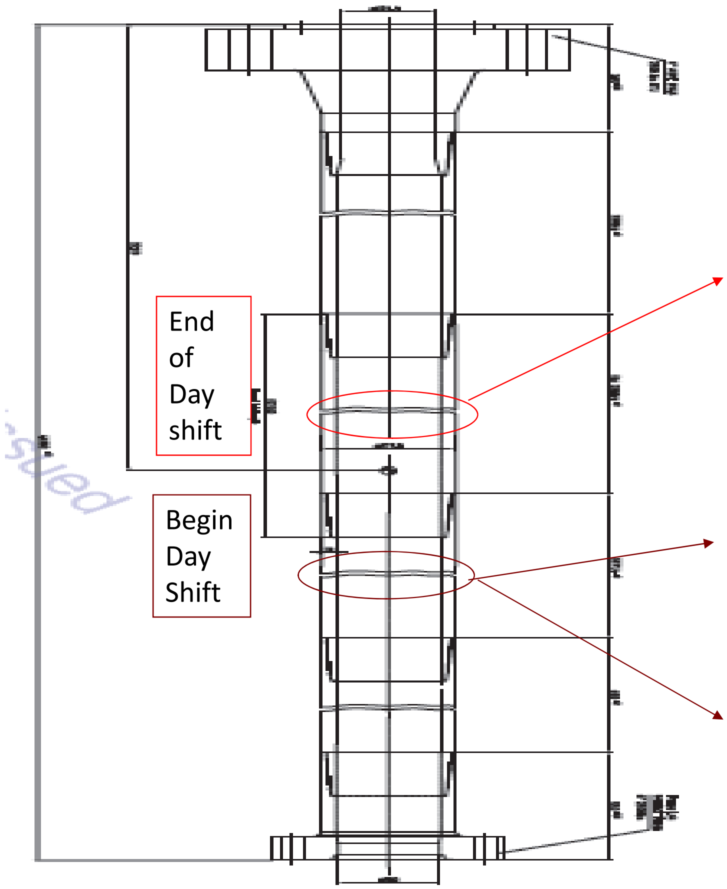
Threaded Connection – (pin) male

Threaded Connection – (box) female

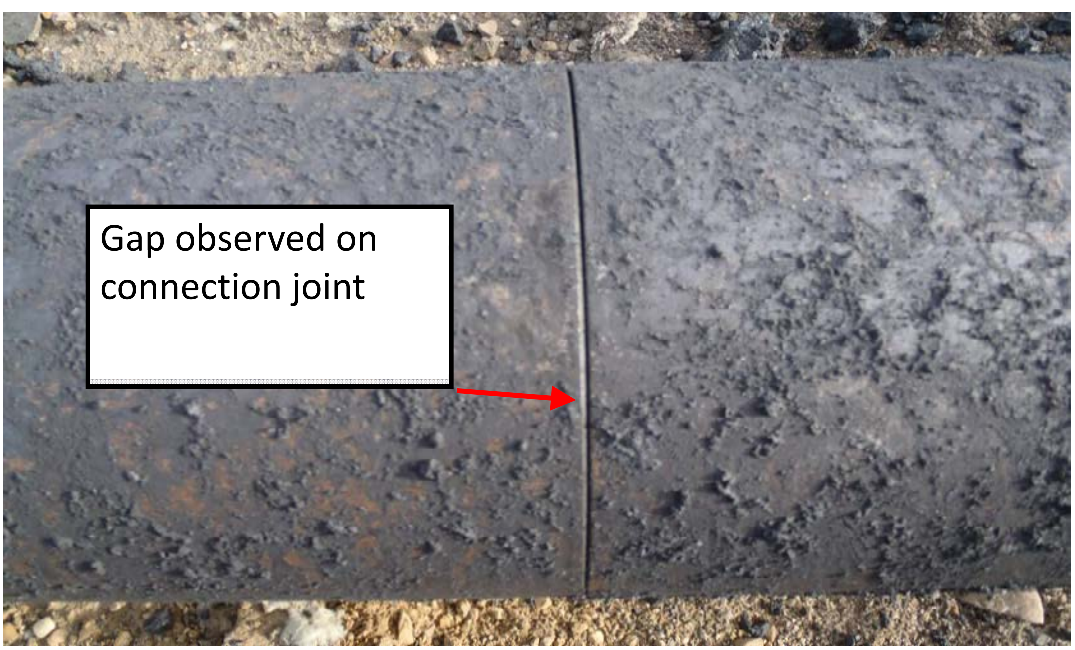
- Female end

Threaded Connection – (box) female

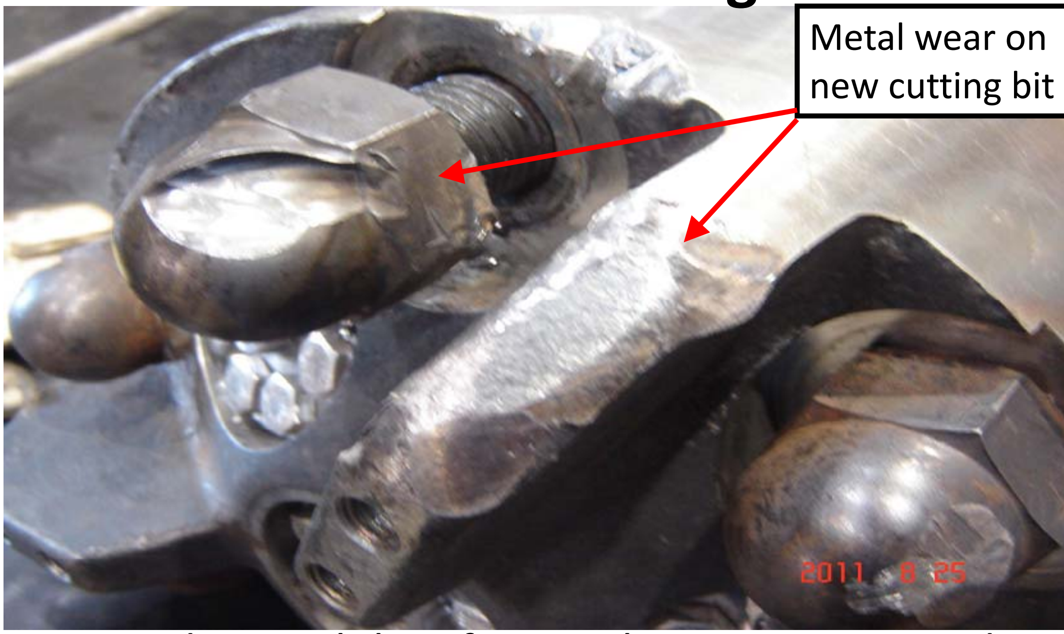
Coker Drill Stems



Drill Stem Couplings

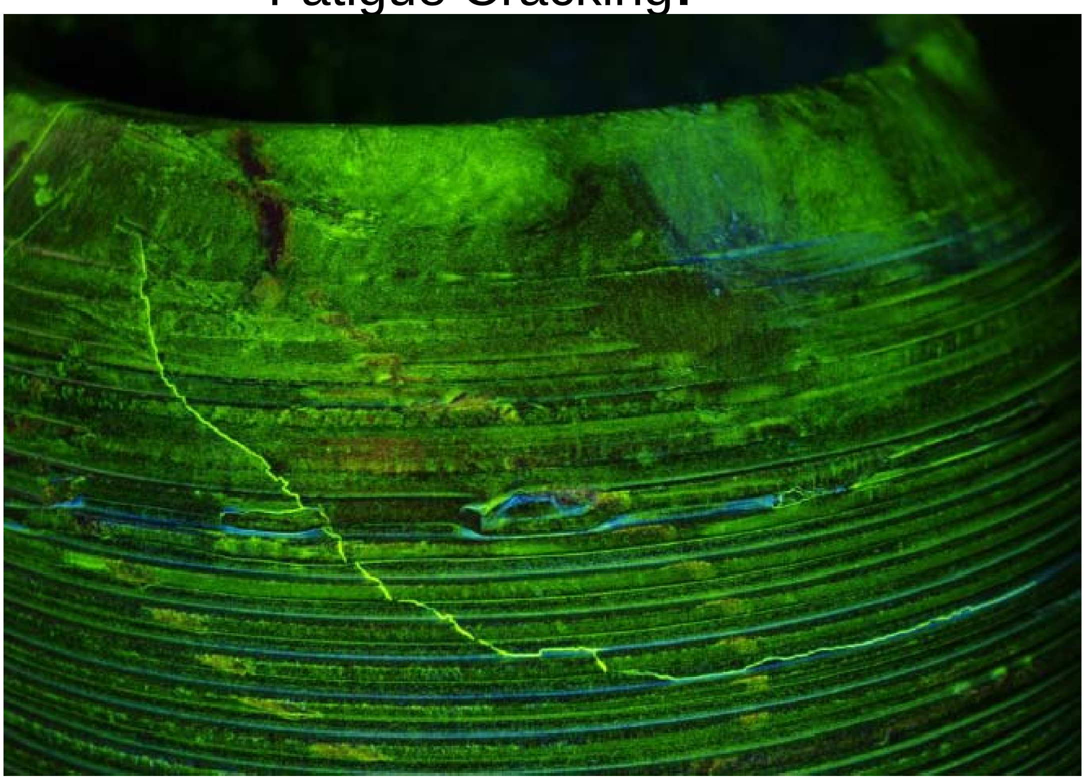


Drill Stems to **Cutting Bit**

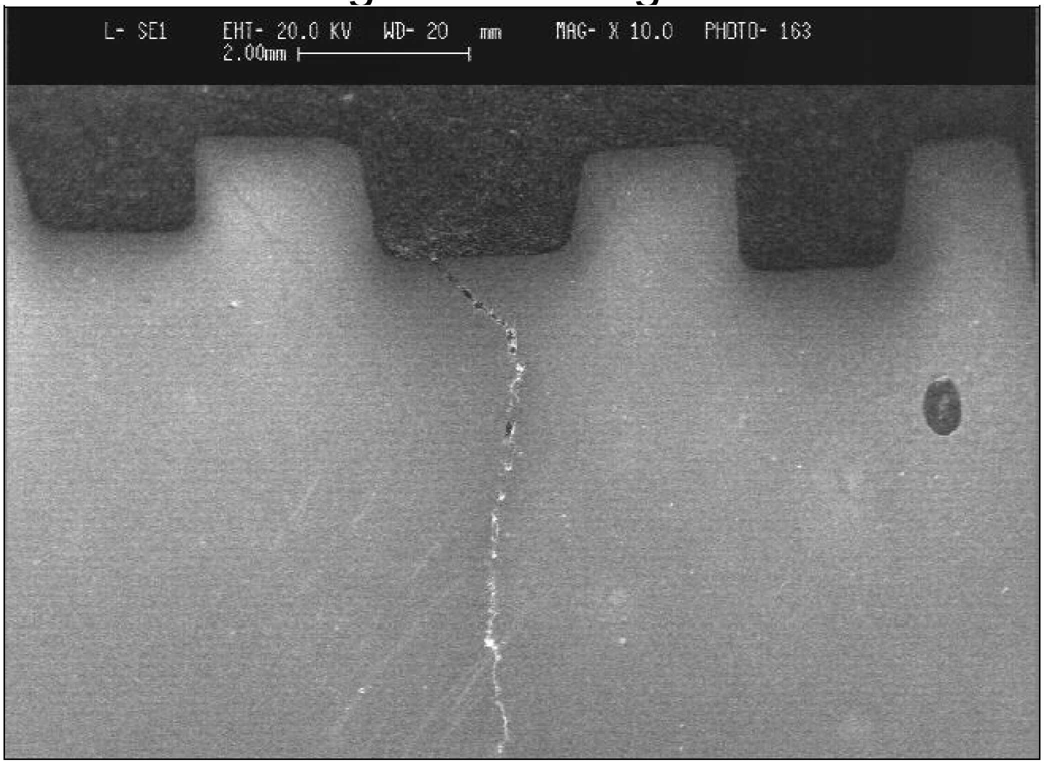


- Scarred nut exhibits from unknown source and found loose.

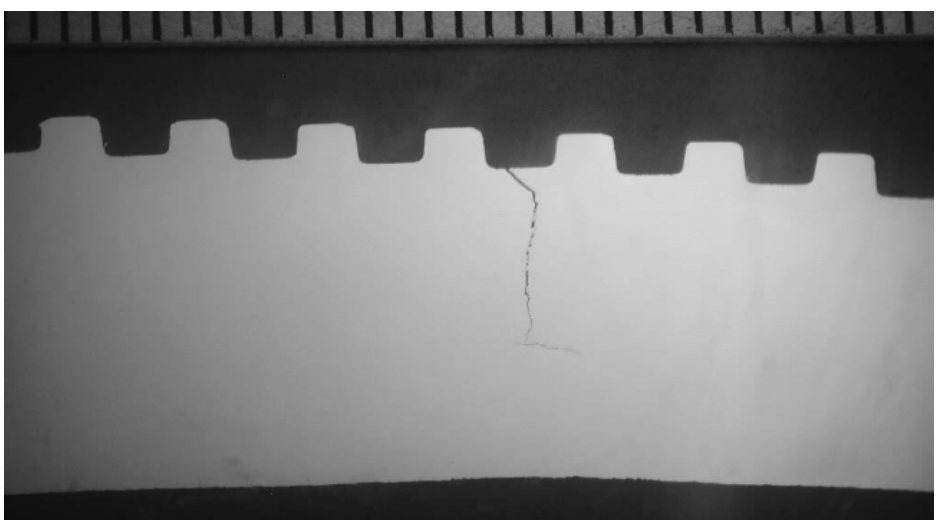
Fatigue Cracking.

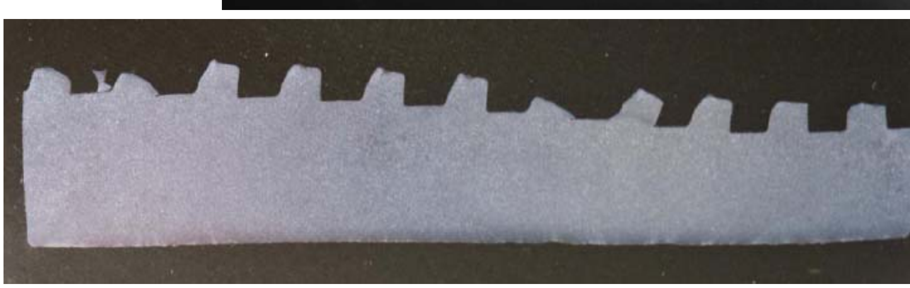


Fatigue Cracking.



Fatigue Cracking





Thread Damage

Potential Possible **Scenarios**

- Consistency of Pipe material quality?
- What is the initial and in-service thread condition?
- Is the correct thread being used – industry practice?
- Is the setup torque correct initially and thereafter?
- Is unwinding or un-raveling occurring ?
- Bending stresses on the stem during operation?
- Is there bending from jet side load (Nozzle plugging issue)
- Mechanical issues

Confirmed Mechanical Scenarios

- No reverse rotation on the stem.
- In normal mode the torque applied by Kelly drive was with-in range .
- Changing pipe segments lengths, affects flexibility.

Next Steps – **Questions** to be answered

Q1. Review industry practice; threads,materials etc

Q2. Metallurgical testing of the pipe material !

Q3. Is the thread appropriate?

Q4. Confirm on actual torque condition throughout (all drums)!

Q5. Confirm possible blockage on the water nozzle in cutting head (possible side load)?

Q6. What is the stress state?

Q7. Review mechanical condition and parameters!

Answers. What was found. Interesting findings.

A1. Pipe material variations ,wide latitude. (more later)

A2. Must correctly choose and verify material purchases

A3. Thread used in a wide variety of drilling. Analysis verified thread carrying capacity OK provided properly tightened.

A4. Actual torque condition ; attention is important.

A5. Bending stresses substantial.

A6. Blockage in water-jet nozzles not sufficient to cause deformation (although side loads can be substantial).

A6a. Drum alignment critical ;no compelling issues found.

A6b. Rub marks on drill stems suggested item 6 relevant.

A1.Drill Stem Tubulars; **Material Condition**

ASTM A516- 4140

ASTM A-519 Heat Treated Conditions Gr.4140	Ultimate Strength (ksi)	UTS (MPa)	Yield Strength (ksi)	YS (MPa)	Elongation (%) ,2in.	Hardness Rockwell (B scale)	Heat Treat (Temp+Soak)
Hot Rolled	120	855	100	621	15	100	Temper10min 500-740C
Stress Reliev'd	120	855	100	689	10	100	30K<Tempering temp.
Annealed	80	552	60	414	25	85	840-900C No soaking
Normalz'd	120	855	90	621	20	100	840-900C No soaking
Oil -Water Quench			>100	>700	<8	>240	Temper 10min 500-740C

A1.DrillPipe ; 4140 Material Properties

Grade 4140	Wall 't' mm(in)	**Heat Treat** Condtn	Yield Strength Mpa (ksi) min /max	Tensile Strength Mpa (ksi)	**Elongation long-transv**	Hardness Properties Method - min - max		
Type 1	{Types 5-9 not ASTM categori zation}	SR	758 (110) min	855 (120)	10	HB	100	200
Type 2		N	758 (110) min	855 (120)	20	HB	100	200
Type 3		A	414 (60) min	552 (80)	25	HB	85	200
Type 4	50.8 (2)	Q	552 (80) / 665 (95)	655 (95)	18-16	HRC		22
Type 5	50.8 (2)	Q	655 (95) / 758 (110)	724 (105)	16.5-14.5	HRC		28
Type 6	50.8 (2)	Q	758 (110) / 965 (140)	862 (125)	14-11	HRC	28	36
Type 7	50.8 (2)	Q	758 (110) min	862 (125)	14-11	HRC		36
Type 8	38 (1.5)	Q	862 (125) / 1034 (150)	931 (135)	12.5-10	HRC		38
Type 9	38 (1.5)	Q	862 (125) min	965 (140)	12.5-10	HRC	30	38

SR=Stress Reliev'd N=Normalized Q=Quench+tempered

A1.Drill Stem Tubulars; **Material Condition**

ASTM A516- 4140

Grade	Carbon	Mang anese	Phos & Sulphur	**Chrom ium**	**Nickel**	Molyb denum
4140	0.38 -0.43	0.75 -1	0.04	0.8-1.1	max 0.25	0.15 -0.25
EN/DIN (42CrMo4)	0.38 -0.43	0.75 -1	max 0.25	0.9 -1.1	max 0.25	0.15 -0.25

Grade	Wall 't' mm (in)	**Heat Treat** Condtn	**Charpy (average) Impact Ave of 3 Specimens**	**Charpy (individual) Impact**
Type4	50.8 (2)	Q	50 J (37 ft-lb)	35 J (26 ft-lb)
Type5	50.8(2)	Q	40 J (30 ft-lb)	28 J (21 ft-lb)
Type6	50.8(2)	Q	27 J (20 ft-lb)	19 J (14 ft-lb)

Path forward – A3. **Thread validation**

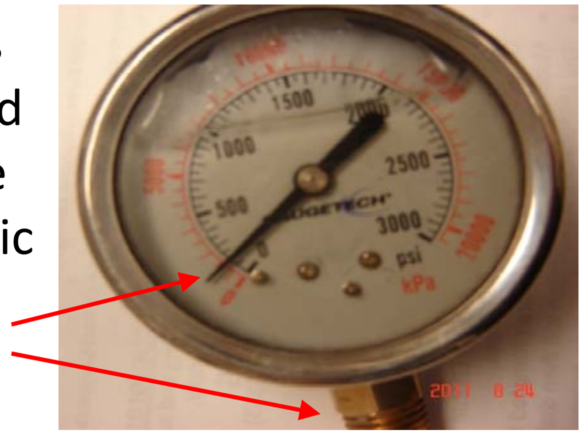
- Avoid galling.
- Connections are weak compared to pipe body
- It is common to estimate point stresses in drill string components with Finite Element Analysis.
- The infinite variety of stress concentrations and load conditions in a drill string make this extremely complex.

Path forward – A4. **Torque**

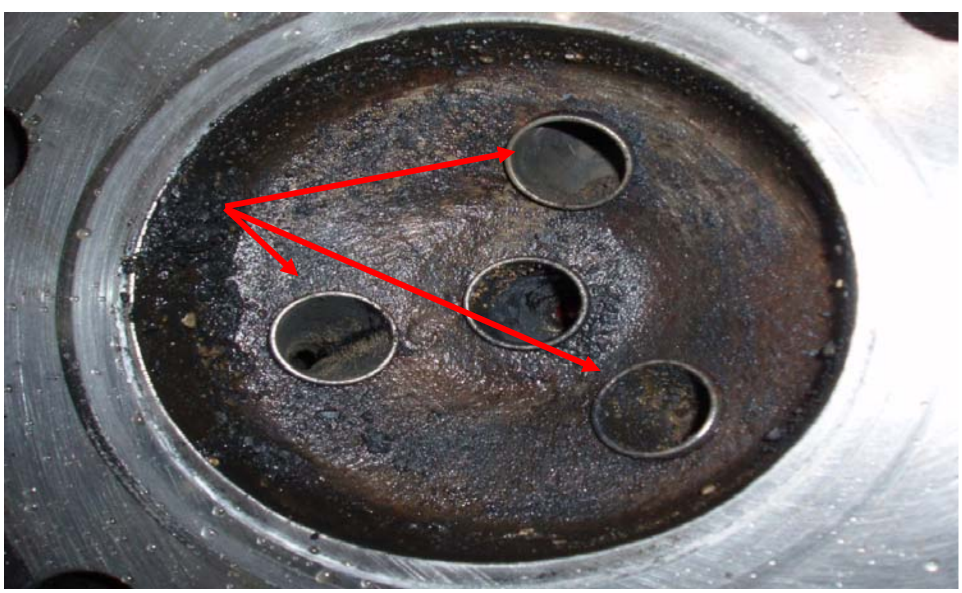
- "Snugged" into shoulder stop is essential to engage the proper interference fit.
- Requires power tightening with suitable thread compound.
- Design parameters must be balanced to reduce the make-up torque
- No bite marks showing from the torque tool (some doubt on torque grip). Validation program successfully implemented.

Path forward – A4. Contd. **Torque**

Hydraulic Torque Gauges need to be zero, calibrated regularly and reading the correct end of the hydraulic cylinder.



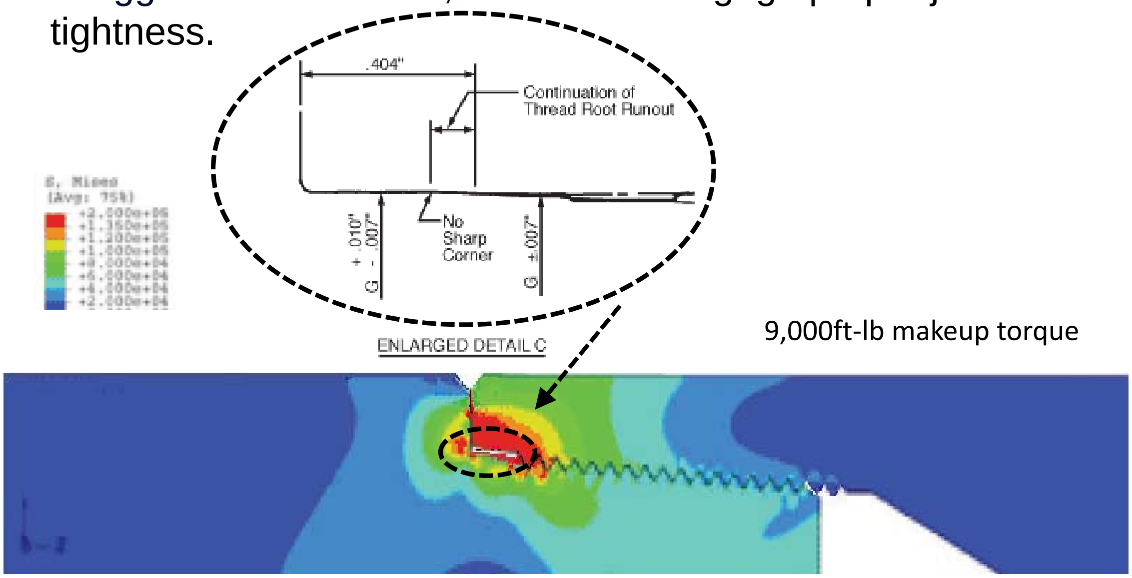
Path forward – A5. **Nozzle-Jet Blockage**

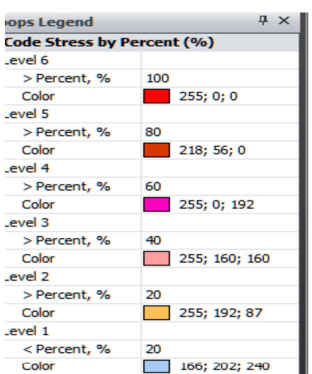


Side cutting nozzles were not plugged ; confirmed by opening the drill bits (eg. above picture)

Path forward – A6. **Stress**

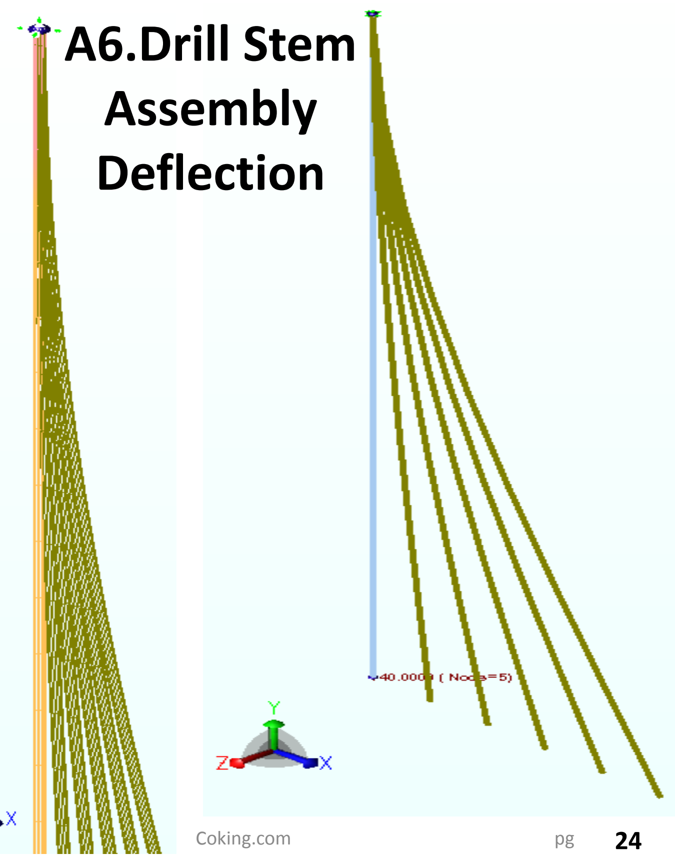
- Strength & load carrying comes from the closing shoulder stop.
- Full torque completion is essential.
- “Snugged” into shoulder; essential to engage proper joint tightness.





ops Legend	
Code Stress by Percent (%)	
.evel 6	
> Percent, %	100
Color	255; 0; 0
.evel 5	
> Percent, %	80
Color	218; 56; 0
.evel 4	
> Percent, %	60
Color	255; 0; 192
.evel 3	
> Percent, %	40
Color	255; 160; 160
.evel 2	
> Percent, %	20
Color	255; 192; 87
.evel 1	
< Percent, %	20
Color	166; 202; 240

A6.Drill Stem Assembly Deflection

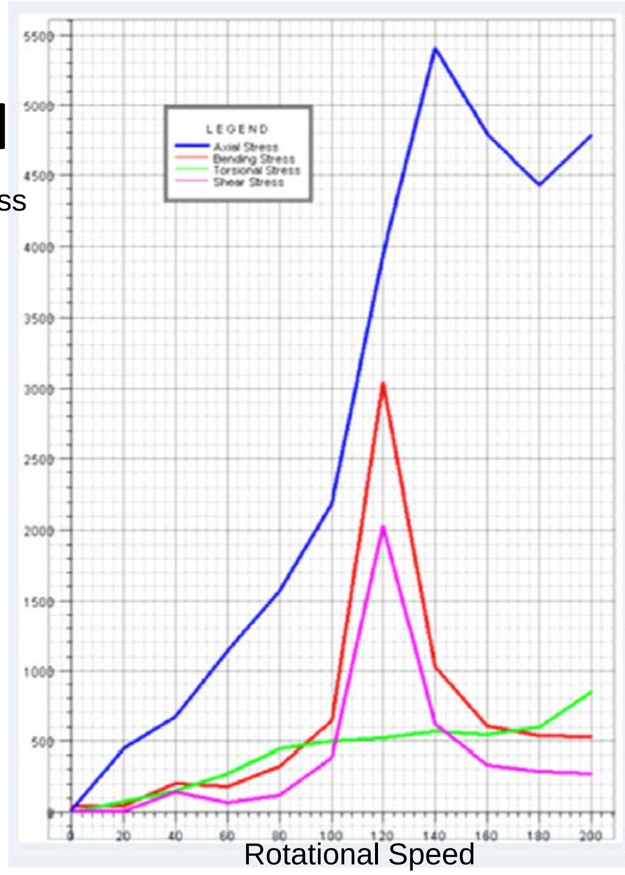


- Small loads can deflect long drill stem assemblies
- Short stiffer assemblies are harder to bend
- Very large loads are required to generate large bending deflections.

A6 Contd. Stress

Rotational speed

- Stress increases with speed up to peak value.
- A critical speed is readily defined.
- All stresses are affected by increased speed with Torsional Stress being *least* affected.

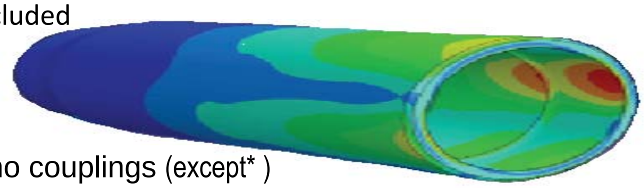


Path forward – A6 Contd. **Stress**

Basic Cylinders-no stress raisers included

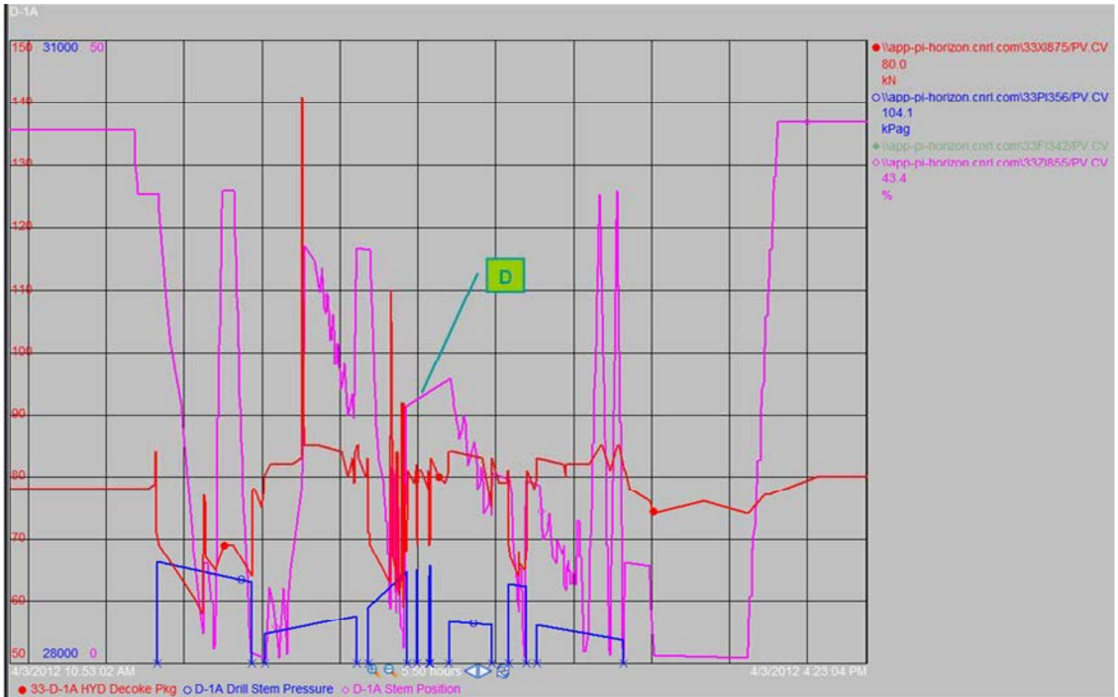
Min.Bending Force = 10 lb (0.04kN)

Min.Vertical Force = 9400 lb (42 kN)

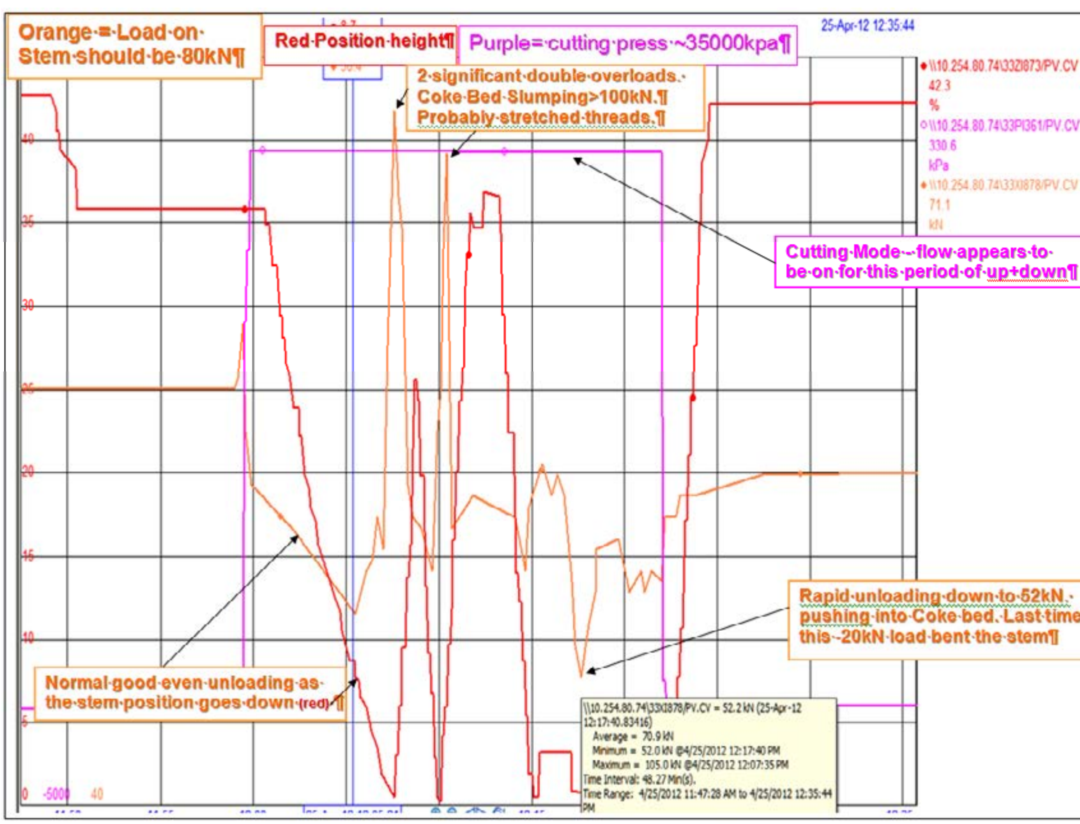


Lateral structural stiffness; Pipe; no couplings (except*)

	Bending Moment ft-lb (kNm)	Bending Stress psi (MPa)	Operating Hoop Stress psi (MPa)	Basic Vertical Axial Stress psi (Mpa)	Von Mises 3D Stress Intensity psi (MPa)
Minimal bend'g ≤1"	155 ft-lb 0.21 kNm	90 psi (0.62 Mpa)	7,500 psi (52 MPa)	3,900 psi (27 MPa)	10,400 psi (71.7 MPa)
Normal bend'g ≤6"	1,000 ft-lb 29.2 kNm	525 psi (3.62 Mpa)	7,500 psi (52 MPa)	3,900 psi (27 MPa)	10,500 psi (72.4 Mpa)
Bend'g. to VessIR =130"	21,520 ft-lb 29.2 kNm	13,000 psi (90 MPa)	7,500 psi (52 MPa)	3,900 psi (27 Mpa)	16,000 psi (110.3 MPa)
1stub length Bnd'g. to VessCone =60" with Couplings *	252000 ft-lb 342 kNm	130,000psi (896 MPa)	7,500 psi (52 MPa)	3,900 psi (27 Mpa)	162,500 psi (1120 MPa)

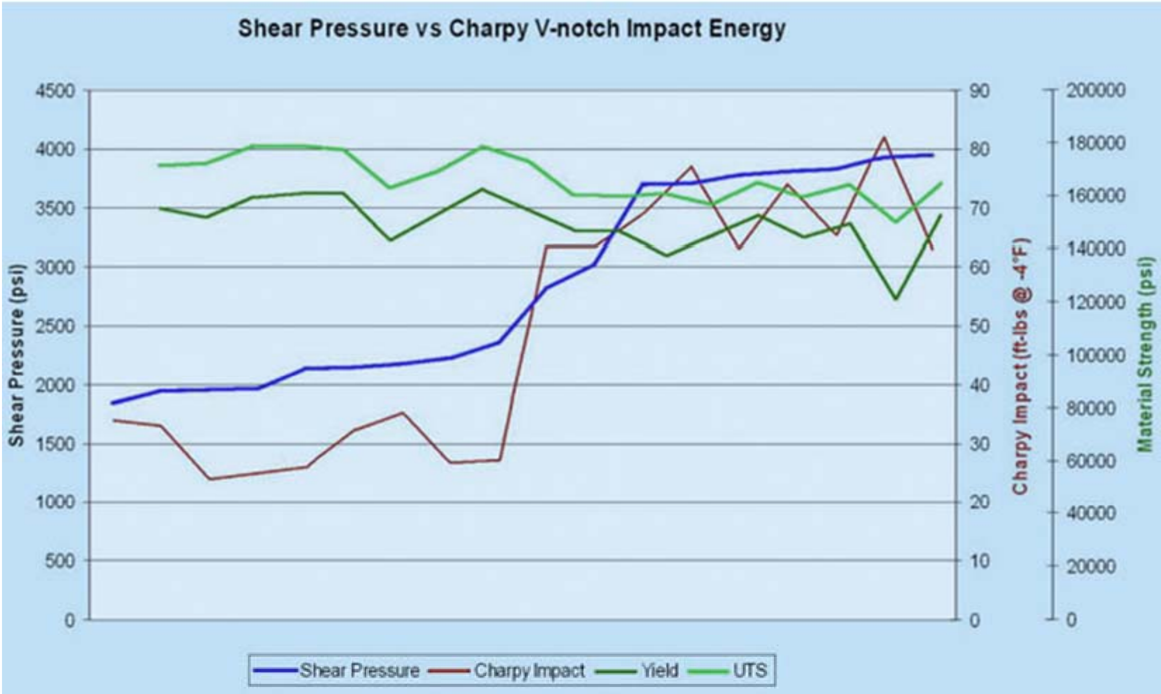


- D = After clearing the pilot hole, the bit was raise to nearly the previous level of the top of the bed. So the tool was in a warm spot for 18 min (1:24-1:42). Unlikely to be as hot as leaving the tool in the cone for an extended period of time. If the tool had be +5m higher, it would have been in a "cool-er" zone.



Path forward – A6 Contd. **Impact Strength**

Shear strength; Impact Strength governs over Material Strength.



Conclusions;

1. Review industry practice; threads, materials etc
2. Need to examine options for thread arrangements.
3. Fit-up & abutting (shoulder seating) is critical.
4. Confirm on actual torque condition.
5. Care in drilling and cutting technique is critical.
6. Coke bed slumping & hardness – difficult to manage.
7. Lower API will create more cutting problems.