Mechanics of Expansion Against the Well-bore

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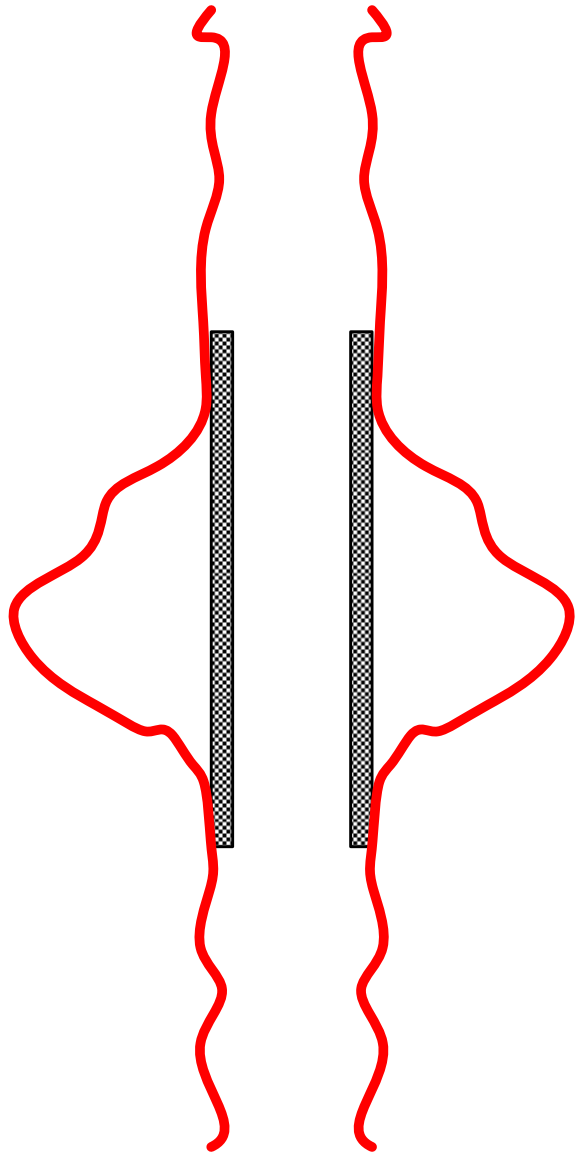
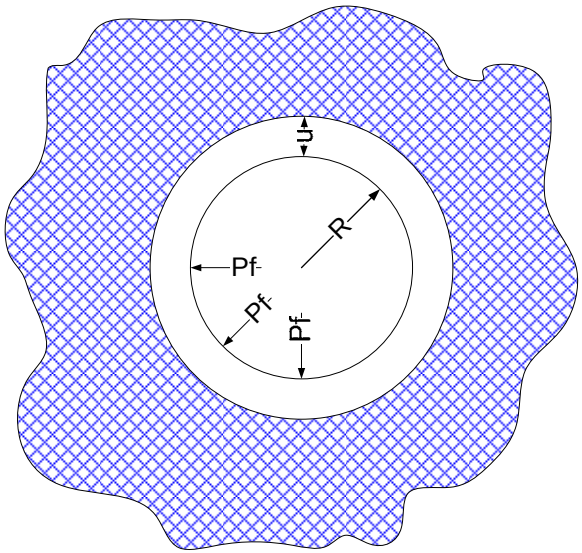
Why Expand against the Well-bore ?

- Mitigation of cementation for sealing.
- Allowing isolation of well-bore ‘Caves’, which are inherently difficult to seal with cement.
- Shale stabilization.
- Extended reach drilling.
- Open hole Liners.
- Open hole Clads.



Mechanics Model of E.A.F.

Linear elastic media with a cylindrical hole of radius R.



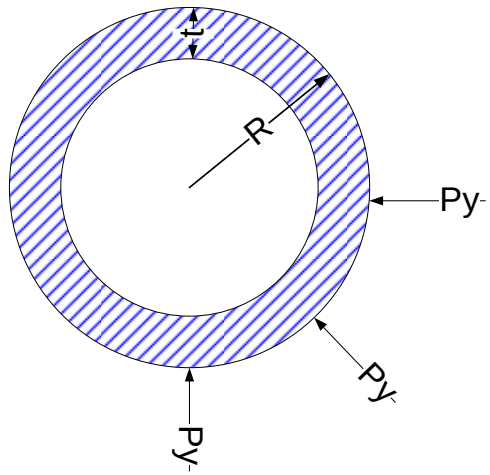
$$P_f = \frac{E}{(1+\mu)} \cdot \frac{u}{R} \quad [1]$$

E = Formation Young's modulus.

μ = Formation Poisson's ratio.

Pipe yielding condition

$$[2] \quad P_y = \frac{t}{R} . \sigma_y$$



Maximum hole expansion [w\o Pipe yield back]

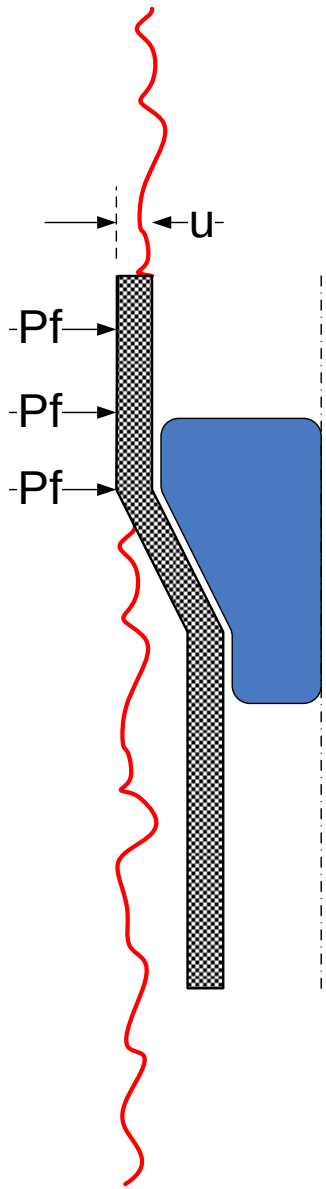
- Condition for the pipe not to yield back after expansion –

$$P_f \leq P_y$$

- Then maximum expansion into the formation –

[3] $$u_{\max} \leq \frac{(1+\mu)}{E}.\sigma_y.t$$

- Example: using $\mu = 0.3$, $\sigma_y = 70{,}000$ psi, $t = 0.3$ inches



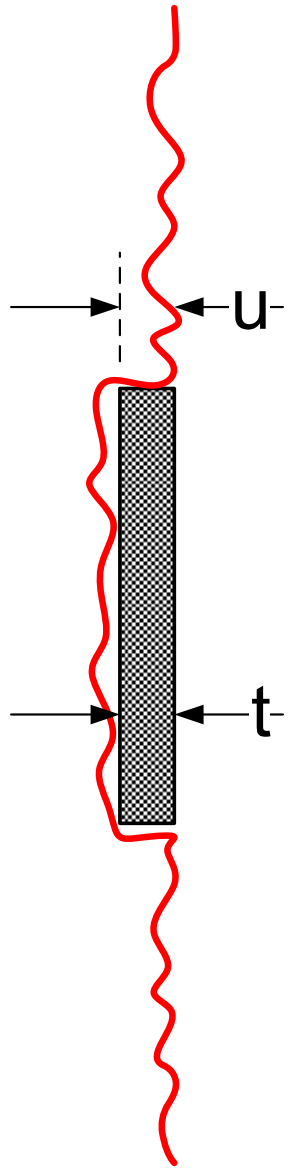
Formation	E [psi]	μ	Umax [inches]
Clay	0.01 – 0.2	-	27 – 1.36
Sand	0.1 – 2	0.2 – 0.35	2.7 - 0.14
Shale	0.9 – 100	0.2 – 0.4	0.3 – 0.003
Carbonates	20 – 80	0.2 – 0.35	0.014 – 0.003

Expansion into Formation – Openhole MonoClad

$D_{hole} = D_{exp}$

u = t into [3]

$$\frac{E}{(1+\mu)} \leq \sigma_y$$



Example: using σ_y = 70,000 psi, μ = 0.3

Therefore pipe can be completely expanded into the formation if the modulus is less than -

$$E = 0.9 \times 10^5 \text{ psi}$$

Expansion into Formation - MonoDiameter

$u = t$

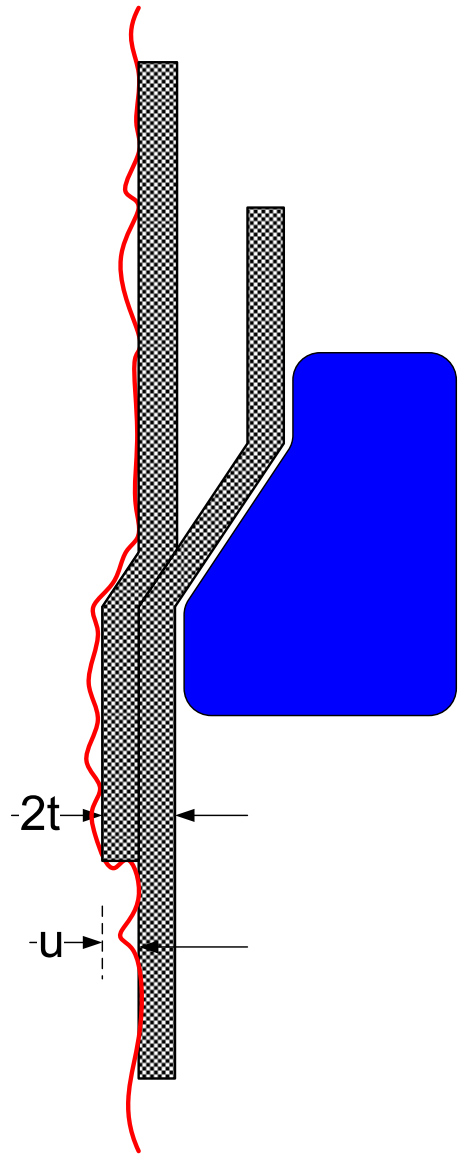
$t_{bell} = 2t$

$$\frac{E}{(1+\mu)} \leq 2\sigma_y$$

Example using $\sigma_y = 70{,}000$ psi, $\mu = 0.3$

Therefore, the MonoDiameter bell can be expanded into formation if formation modulus is less than -

$$E = 1.8 \times 10^5 \text{ psi}$$



Pipe Extrusion

If the formation pressure on pipe reaches pipe yield stress, the pipe material is extruded between the cone and formation and the pipe elongates.

[4] $$u_f \le (1+\mu)\frac{\sigma_y}{E}.R$$

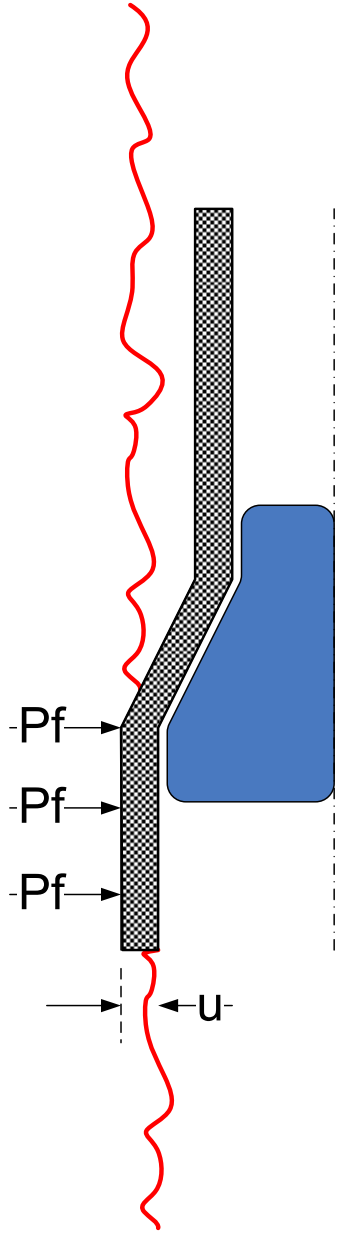
Example: using

$\mu = 0.3$, $\sigma_y = 70{,}000$ psi,

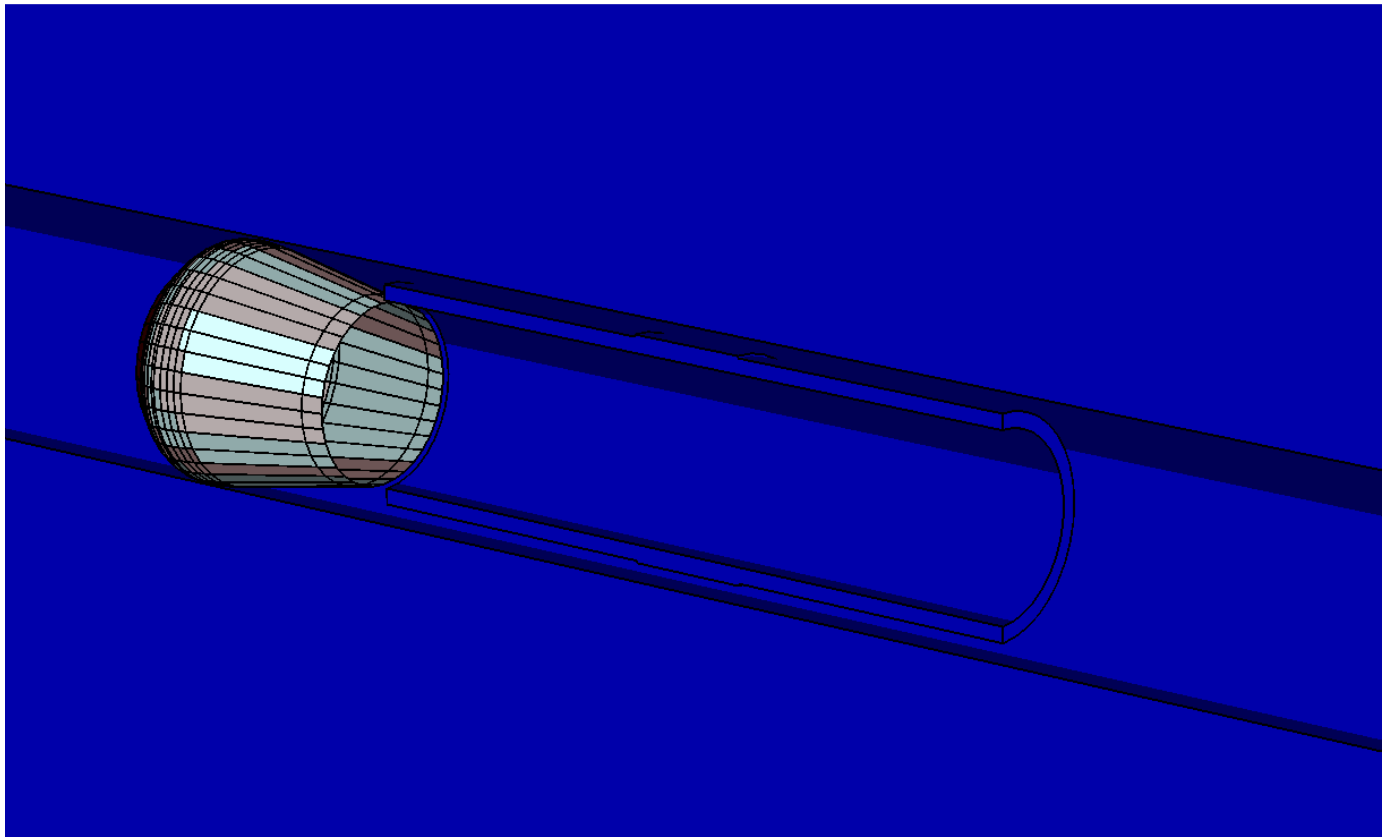
$E = 60 \times 10^5$ psi, $R = 6.125"/2$

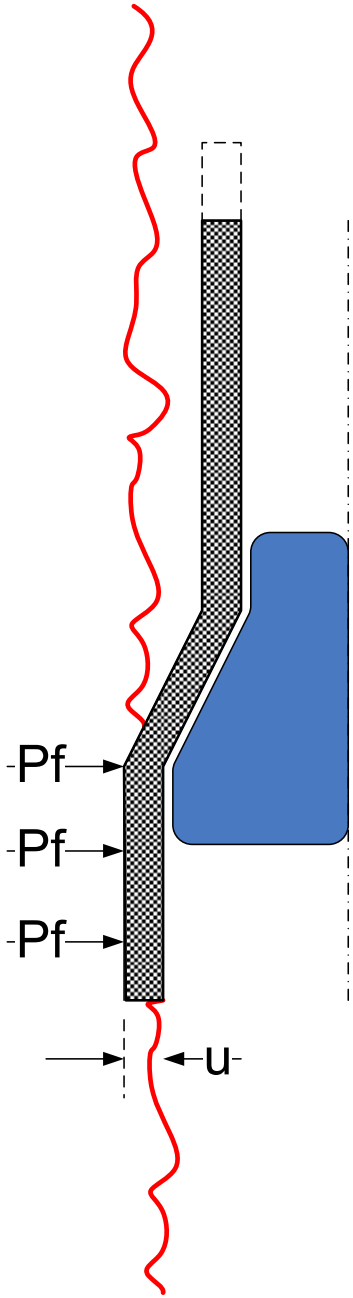
Maximum formation expansion before pipe extrusion

$u_{ext} = 0.046"$



Pipe Extrusion - Movie

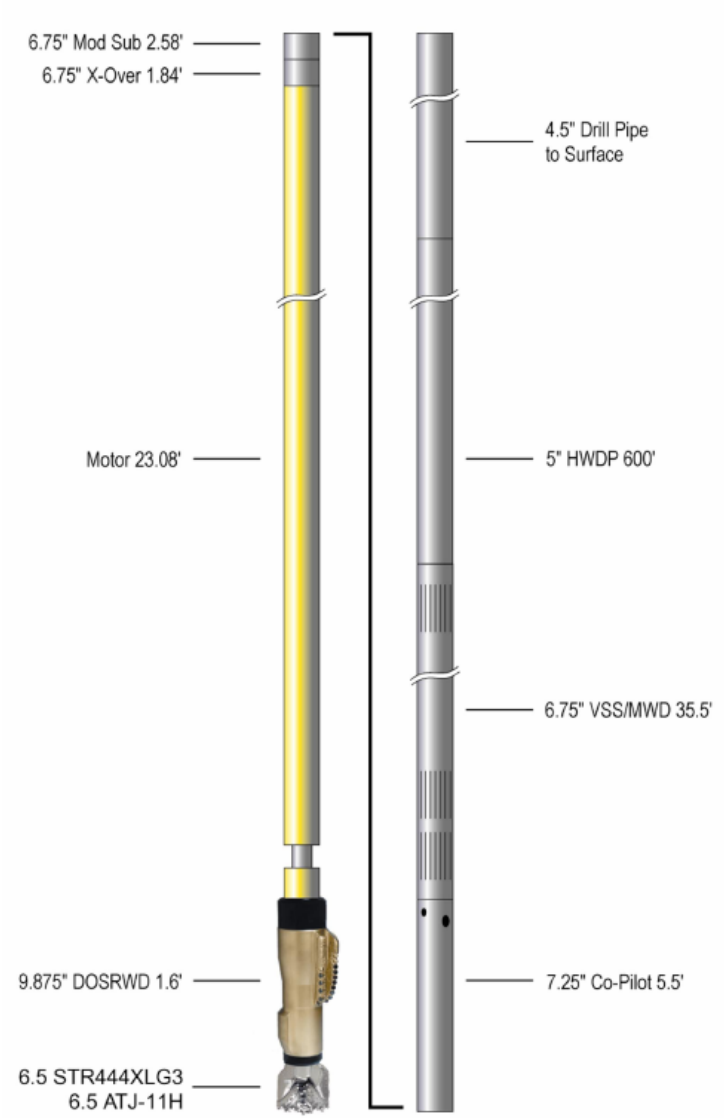




Open Hole Geometry

- Referring to SPE 67769 - Determination of Borehole Quality, Diameter and BHA Directional Response: Eccentric Tool Test Program for Expandable Casing Application North Sea.

- BHA included a 6.5" pilot, **9.875"** DOSRWD & 6.75" medium speed directional motor.
- Lithology – Pennsylvanian shale, [BETA, South of Tulsa, near Glenpool field]
- The average hole size was measured <10.5", with a minimum diameter of **9.69**".



Hole Geometry Example

1. With the following parameter's given –
   - $OD_{expansion} = D_{hole\ nominal} = 9.875$"
   - $E = 6 \times 10^6$ psi
   - $\mu = 0.3$
   - $\sigma_y = 70{,}000$psi
   - $t = 0.350$"

2. The maximum hole expansion, before formation yields pipe back can be calculated from formula [3] –
   - $\Delta D_{max} = 0.010$"

3. The maximum hole expansion before pipe extrusion by formation can be calculated from formula [4] –
   - $\Delta D_{ext} = 0.150$"

Hole Geometry Example

4. At the minimum hole diameter, D_{min}, hole needs to be enlarged –
   - $\Delta D = OD_{exp} - D_{min} = 0.185$”

5. Pipe will be extruded since -
   - $\Delta D > \Delta D_{ext}$

6. Drift Diameter will be less by –
   - $D.D. = \Delta D - \Delta D_{max} - \Delta D_{wall} = 0.140$”

Conclusion – For hard formations expansion system should be designed based on minimum hole diameter.

Summary

1. Evaluate formation elastic properties.
    - Young's Modulus
    - Poisson's Ratio
2. Evaluate expected minimum hole diameter.
3. Estimate maximum hole expansion using formula [3].
4. Talk to service company which understands Expansion Against the Formation.

THANK YOU

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