Weatherford®

Well Screen Technologies

FEA Modelling of Expandable Sand Screens Interactions with Rock Formations

Ken Watson and Colin Jones; Weatherford International

SCC2009 SIMULIA Customer Conference

May 18-21, 2009 – The Brewery, London, U.K.

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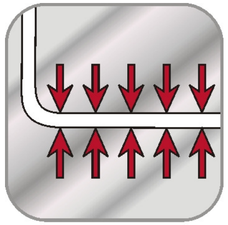
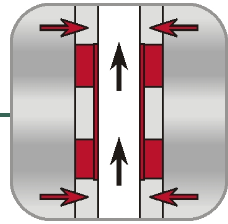
Solving your sand control challenges.

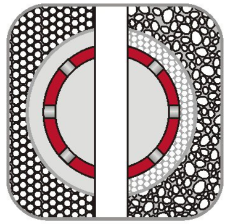
High Productivity



Optimum Drainage



Effective Isolation

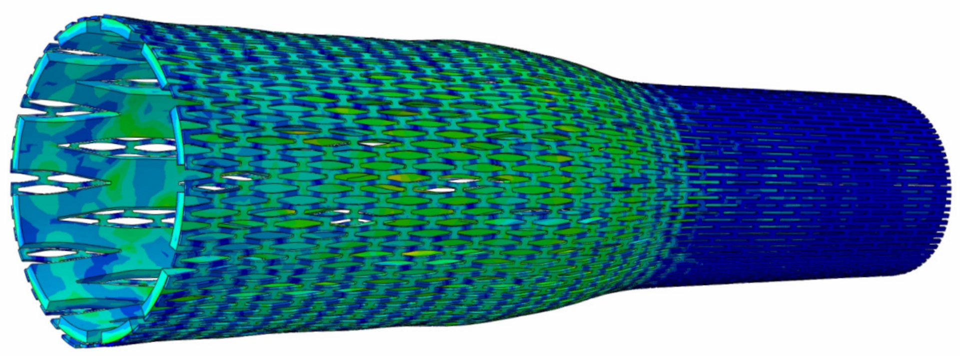


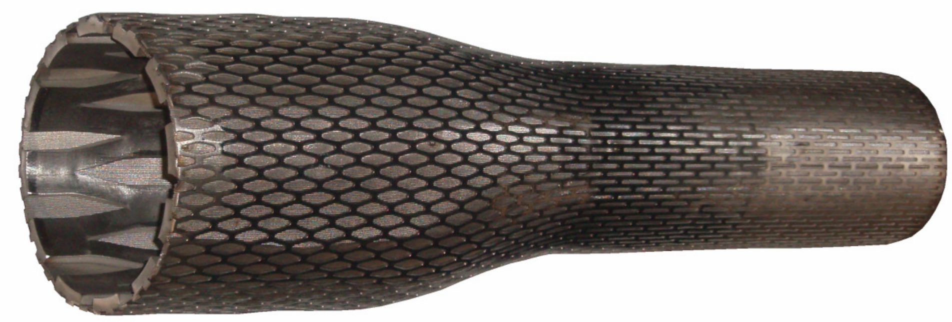
Application Versatility

Integrated Function

Presentation Overview

- Introduction; ESS® products / installations
- Geomechanics and ESS – EWBS example
- Meshing of slotted ESS and the subsequent Equivalent ESS
- Oilwell lifecycle and re-circularization
- Vertical-Horizontal Well Application Screening Tool
- Inclined Wellbore in a Sand Shale Sequence
- Conclusions
- Q and A





Introduction; ESS® products

Expandable Sand Screens (ESS ®) are a relatively new sand control product.

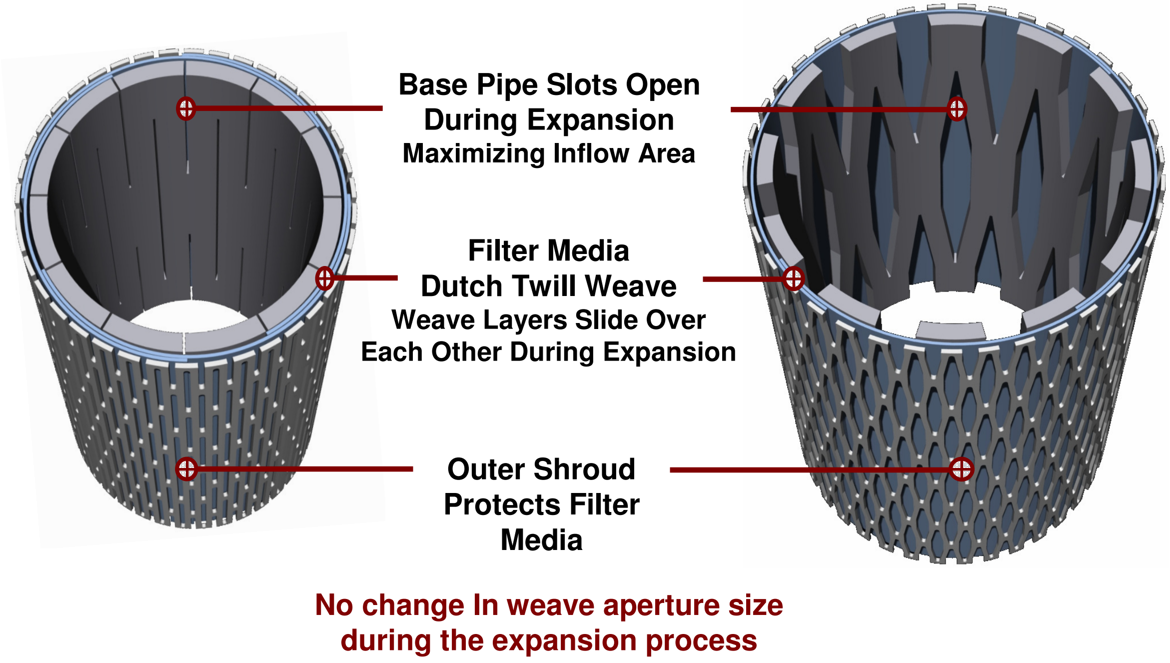
There have been approximately 800 installations worldwide (over all vendors).

They come in two different types; a system based on slotted basepipe (shown here) and a system based on drilled basepipe.

The slotted basepipe is most common with around 600 installations since 1997.

Slotted basepipe; easy to expand into full contact with wellbore (no matter the shape). This compliant system has advantages in well productivity, sand retention capability and reliability.

Drilled basepipe; it is strong, but difficult to expand, especially in an irregular wellbore

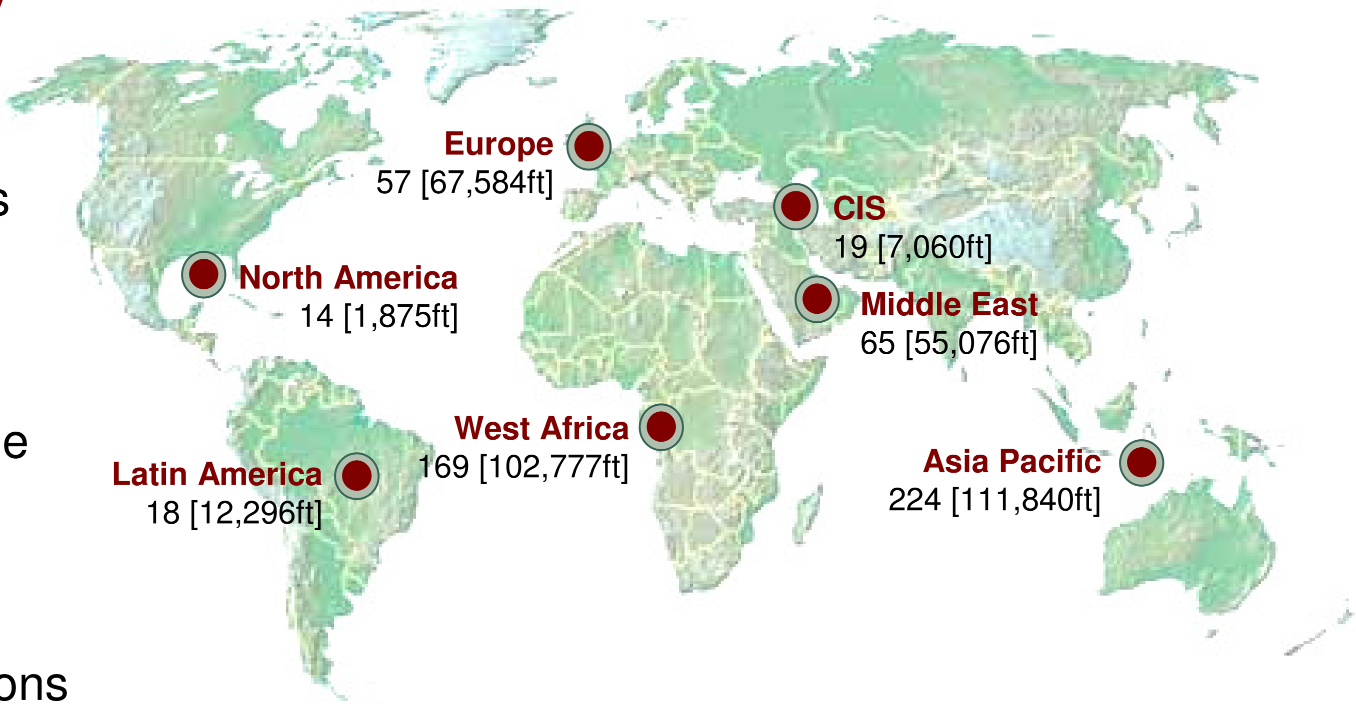


Details of the construction of ESS

Introduction; ESS® Installations

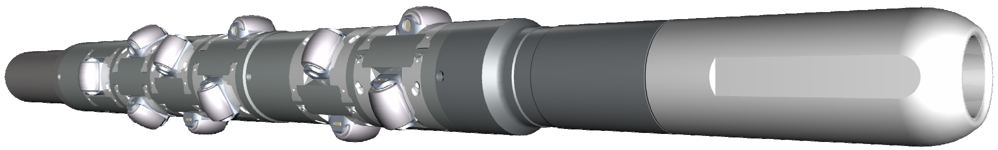
Applications History

- Oil, Gas, Water
- Producers, Injectors
- Vertical, Deviated, Horizontal
- Single and Multizone with Isolation
- Multilaterals
- Intelligent Completions



>570 installations / > 360,000 installed footage / >2,000 years of production history

As of January 2009



The **ACE tool** (Axial Compliant Expander) offers compliant expansion to eliminate the annulus & provide borehole support.

Introduction; ESS® / Joint Industry Project

The relatively low strength of the slotted basepipe *ESS* was initially a concern, but early testing with small scale systems showed that the *ESS* greatly strengthened the wellbore, especially when in full compliant contact!

A joint industry project (JIP) was undertaken to understand how the full size ESS would react in a wellbore of weak sands and sandstones. The high stresses experienced in a downhole situation were mimicked in a large pressure vessel or poly-axial cell.

The results of these tests showed that for any reasonable reservoir material there was very little deformation of the ESS. The only situation where large deformations were experienced were for very low friction angle shales.

Geomechanics and ESS – EWBS example

When the hole is drilled, the stresses within the wellbore are distributed. This creates a yielded zone. When the mud overbalance is removed, the yielded zone grows, causing a reduction in the wellbore diameter – against and straining the ESS.

Weatherford developed an Expandables Wellbore Stability Model (EWBS) to analyse the rock / ESS interaction. Deformation of the ESS to depleted reservoir pressure is limited to 20%.

The JIP tests were also used to calibrate and verify the EWBS and then actual field measurements from subsequent installations have confirmed the model's accuracy.

Well Properties

Depth	9381	ft
Overburden	9381	psi
Max Horizontal Stress	5717	psi
Min Horizontal Stress	5717	psi
Initial Pore Pressure	4200	psi
Final Pore Pressure	1900	psi
Azimuth (SHmax)	0	degs
Inclination	90	degs
Hole size	8.50	inch

ESS Properties

ESS Size	7" 316L	inch
Nominal OD	8.50	inch
ESS Eff. Mod	24742	psi
ESS Yield	300	psi
ESS Hardening Modulus	763	psi

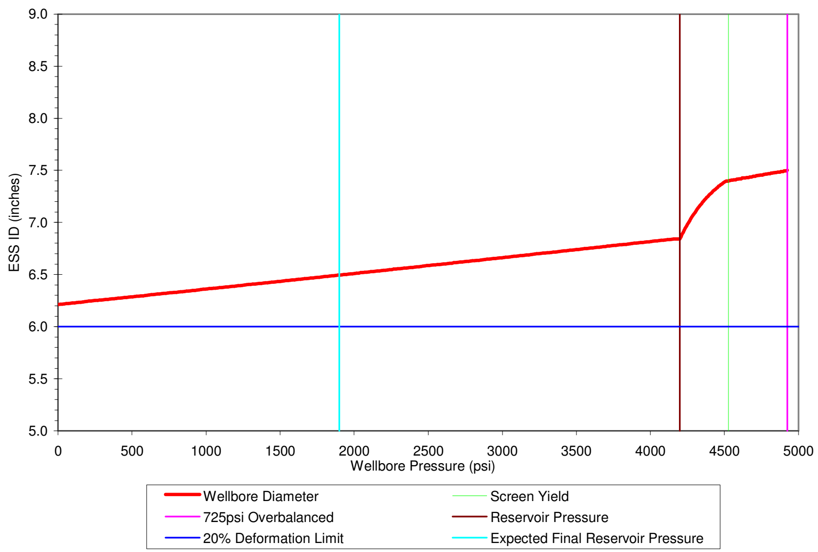
Formation Properties

Unconfined Compressive Strength	215	psi
Triaxial Stress Factor	2.5	psi/psi
Friction angle	26.5	degs
Cohesion	68.0	psi
Dilatancy	0.01	dV/V
Yielded Material Cohesion	15	psi
Initial Reservoir Permeability	n/a	mD
Yielded Reservoir Permeability	n/a	mD

Deformation & Depletion

Yield Zone at Installation	13.00	inch
Deformation Limit	20	%
Wellbore Pressure @ Limit	0	psi
Maximum Depletion/Drawdown	4200	psi

Weatherford Expandables Wellbore Stability Model (EWBS)



Mud Calculations

Over Balance	725	psi
Wellbore Pressure	4925	psi
Mud Weight	10.1	ppg
Yield Zone	3.06	radii
Yield Depth	13.00	inch
Volume Increase	4.75	cu inch
Hole ID bef ream	8.14	inch

Well Details

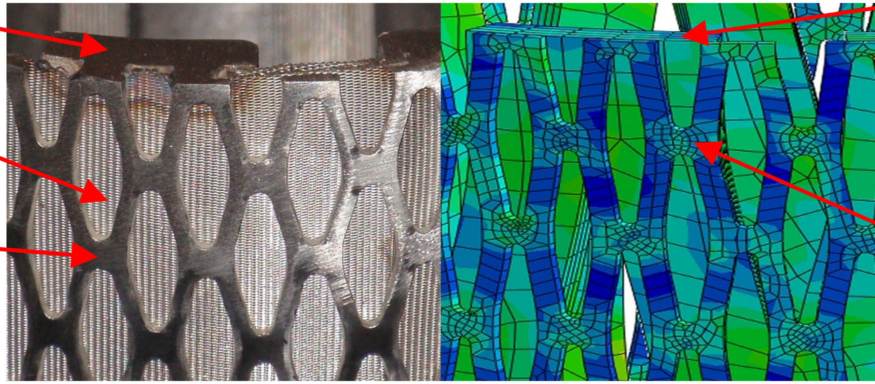
Client	
Well	
Field	
Region	
Comments:	

The analysis in this example was based on a UCS of 215psi and a friction angle of 26.5°.

The EWBS model predicts a maximum of 8% reduction in ESS ID at a 1900psi final wellbore pressure using the 7" ESS.

This is well within the levels of actual stable deformation observed in large scale experiments.

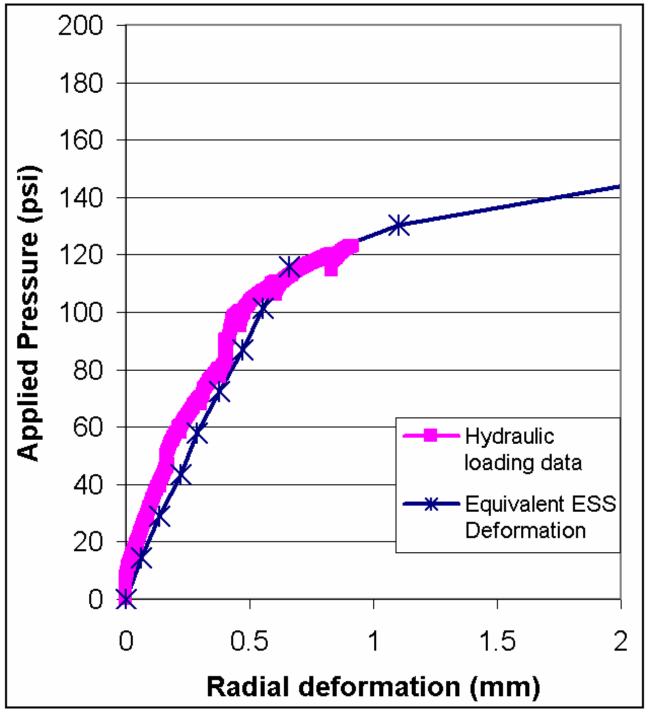
Meshing of Slotted ESS and the subsequent Equivalent ESS



Detail of ESS construction showing complexity of the meshing on the shroud

Earlier models that were analysed and compared to physical tests were adequate as a design tool but too slow for an analysis tool for screening multiple application scenarios.

Therefore a simple representation of the ESS was developed. This equivalent ESS was a plain pipe with the ID/OD dimensions of expanded ESS. The Elastic and Plastic properties were adjusted to fit hydraulic collapse data and FEA models of the whole slotted system



Comparison of the measured deformation;
(1) the full scale simulation and
(2) the equivalent (simple representation) simulation

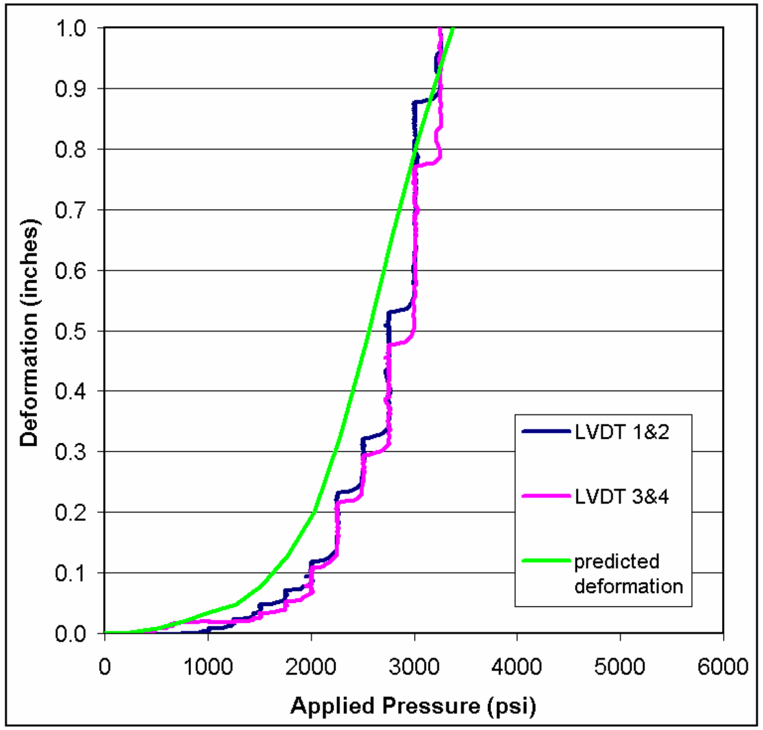
Equivalent ESS

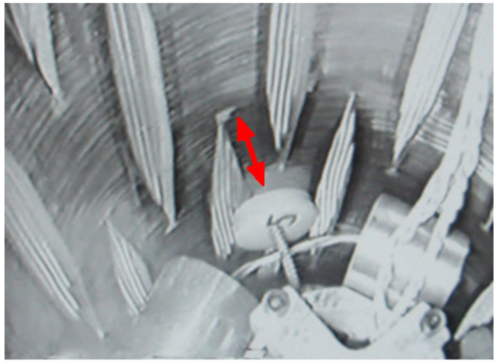
Confirming the Equivalent ESS does match existing data;

Thick Walled Cylinder (weak sandstone), stresses applied to simulate burial of between 15,000 and 20,000ft.

Deformation starts around 500psi, accelerates rapidly, attaining 1" deformation around 3000psi.

The FEA Equivalent ESS plain pipe gives a good match





Oilwell lifecycle and re-circularization

Wellbore is drilled through rock at depth, the removal of material causes a concentration of stress in the formations close to the wellbore.
Failure of near wellbore if the formations are weak.
Any wellbore movement needs to be reamed off to allow drillbit removal and the later installation of the sand screen completion.

In the FEA simulations, two separate models are used.

Firstly, a model with the correct geometry has the initial stresses applied.
This causes change in the wellbore shape.

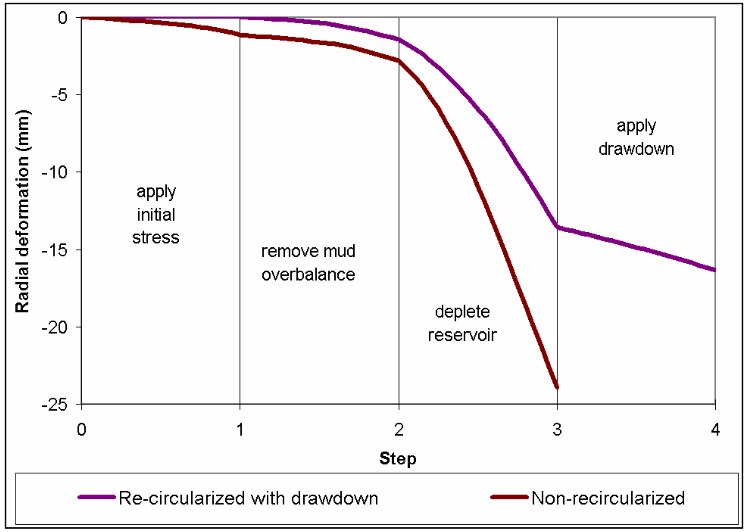
Secondly, another model, identical to the first, has the stresses mapped over it. This allows for an undeformed model carrying the loaded/stressed state.

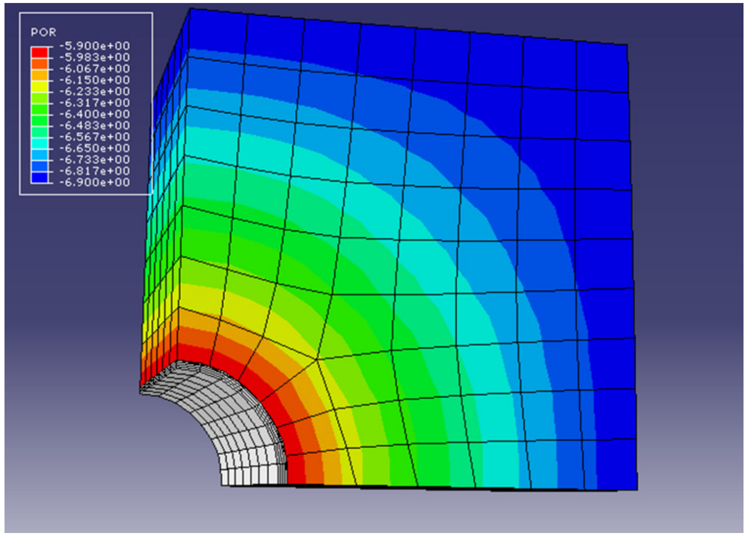
The *map solution keyword is used.

It is always worth checking that the state at the end of the first analysis is identical (or at least comparable) to that at the start of the final analysis. We did find a slight variance of 5%, which was considered acceptable.

Vertical-Horizontal Well Application Screening Tool

A tool for screening potential applications for excessive deformation;
simple enough to be run on a **basic laptop**!





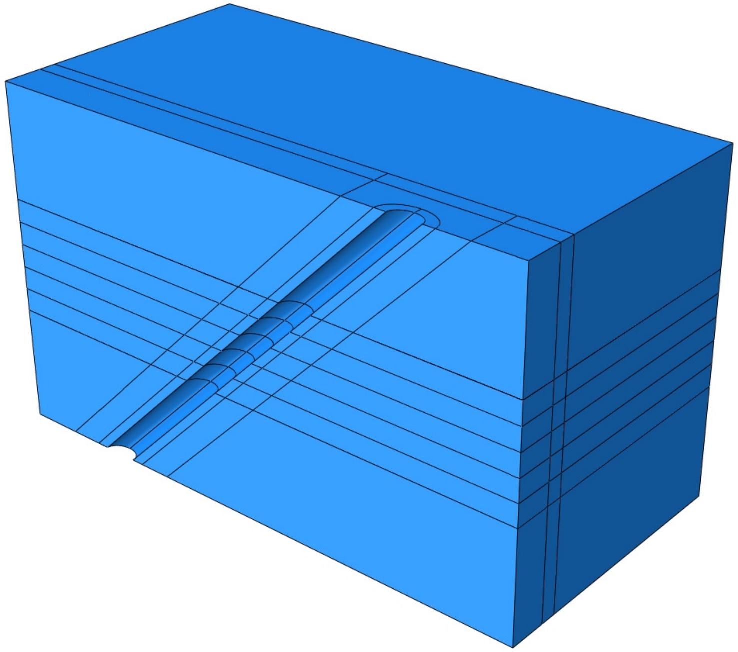
Depth	1900m
Vertical Stress	35MPa
Horizontal stress	32MPa
Initial reservoir pressure	19.2MPa
Mud overbalance	3.5MPa

Table 1Well parameters

Rock	Sandstone	Shale
Density	2500kg/m3	2500kg/m3
Young's Modulus	2069MPa	1379MPa
Poisson's Ratio	0.16	0.16
Friction Angle	20 degrees	13 degrees
Dilatancy Angle	0 degrees	0 degrees

Table 2 Material properties of the sandstone and shale used in the simulations

Inclined Wellbore in a Sand Shale Sequence

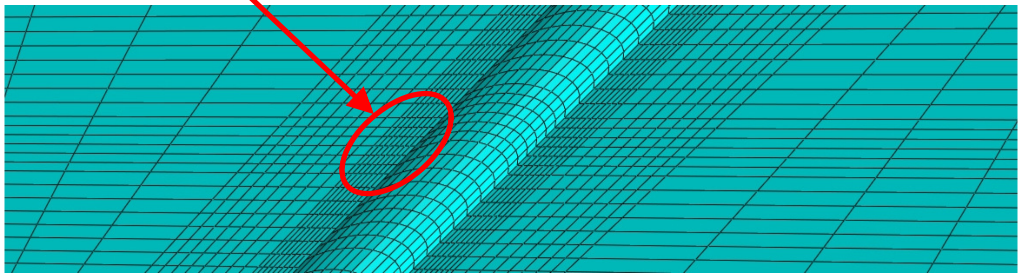


Inclined wellbore in a 5m x 5m x 3m block

Block was partitioned to allow for finer meshing closer to the wellbore.

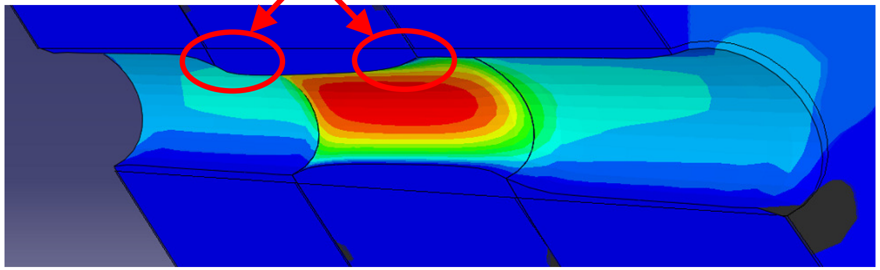
The central section is split into 5 sections which allowed shale layers from 0.2m to 3m to be modelled.

Very fine mesh at middle of block



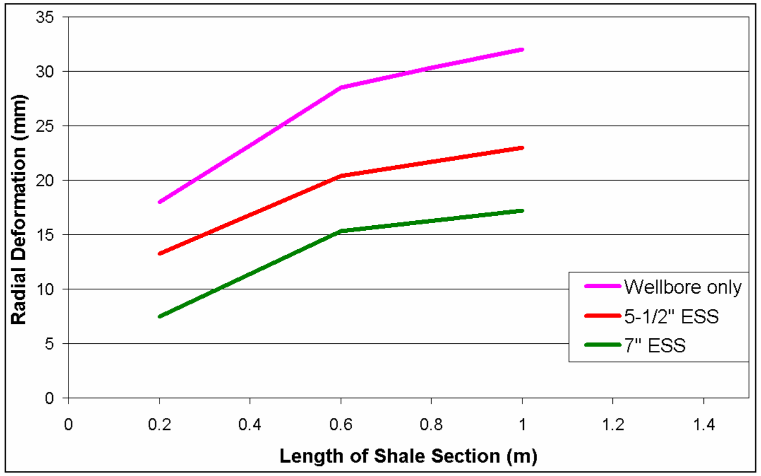
Detail of applied finer mesh close to the wellbore

Sand appears to support the shale at the interfaces



Detail of the deformation in the Sandstone and Shale

Deformation in the central shale as a function of shale layer thickness.



Three sets of simulations were run.

(1) A bare 8-1/2” wellbore with 0.2 – 1m layers of shale.

(2) A 8-1/2” wellbore with 5-1/2” ESS installed, expanded out to 8-1/2” OD (with 0.2 – 1m shale)

(3) A 8-1/2” wellbore with 7” ESS installed, expanded out to 8-1/2” OD (with 0.2 – 1m shale)

Depth	1900m
Vertical Stress	35MPa
Horizontal stress	32MPa
Initial reservoir pressure	19.2MPa
Mud overbalance	3.5MPa

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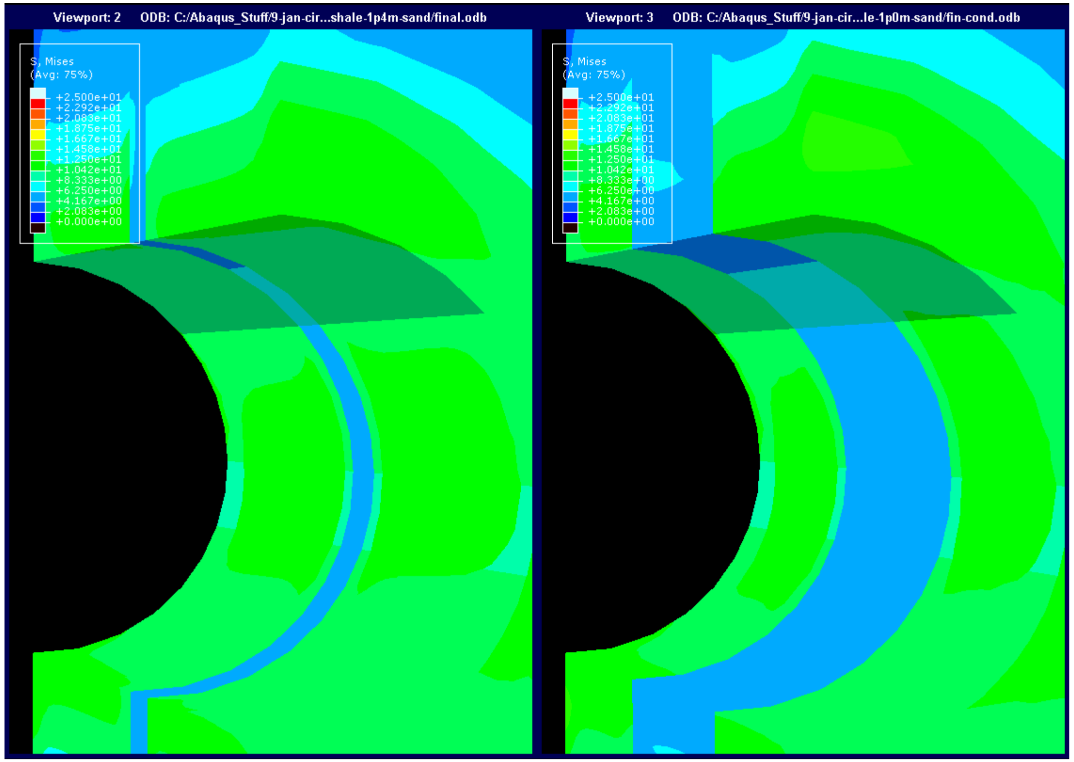
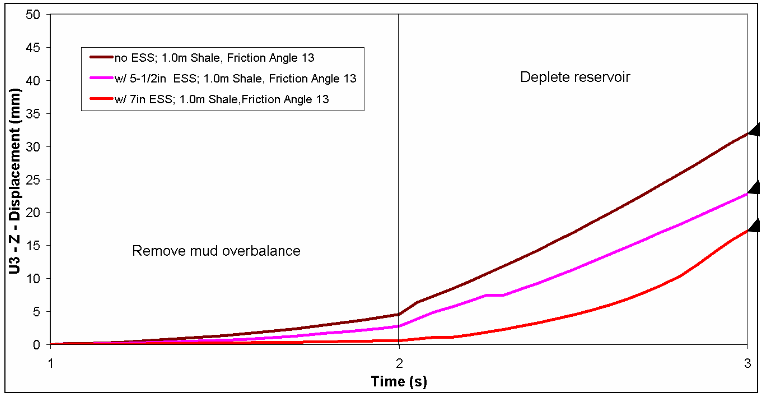
Table 2 Material properties of the sandstone and shale used in the simulations

0.2 metre shale section **1 metre shale section**



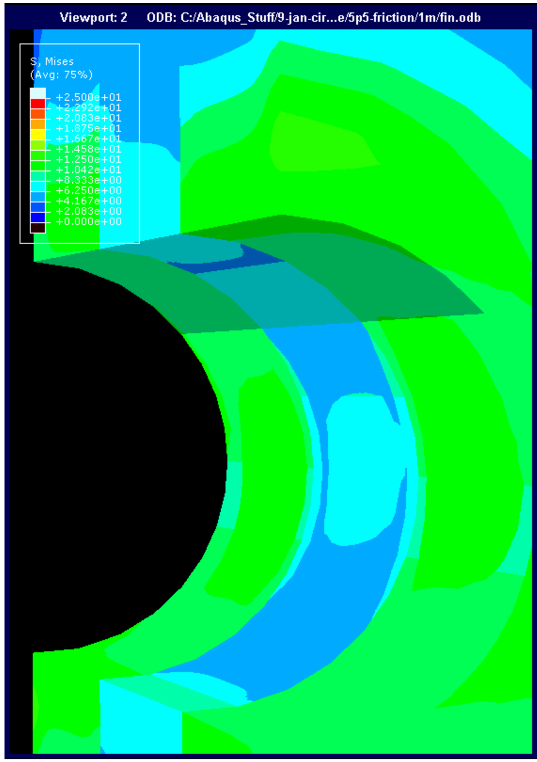
Deformation in the central shale as a function of shale layer thickness.



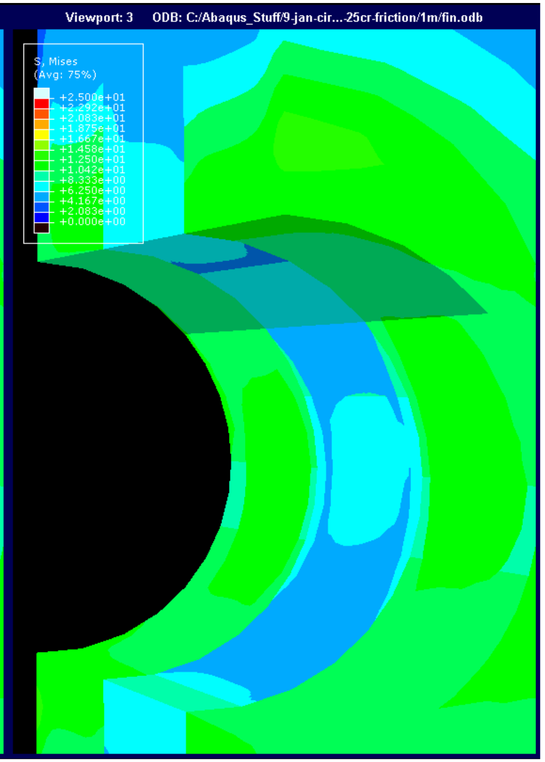
1m shale section	29% deformation
1m shale with 5-1/2" ESS	21% deformation ✘
1m shale with 7" ESS	16% deformation ✓

It is clear to see that the deformation starts earlier in the 5-1/2" ESS system and is far less in the wellbore with 7" ESS present

Wellbore with 5-1/2" ESS



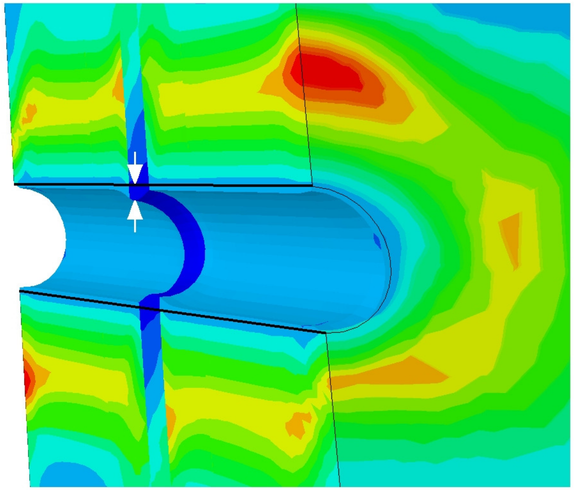
Wellbore with 7" ESS



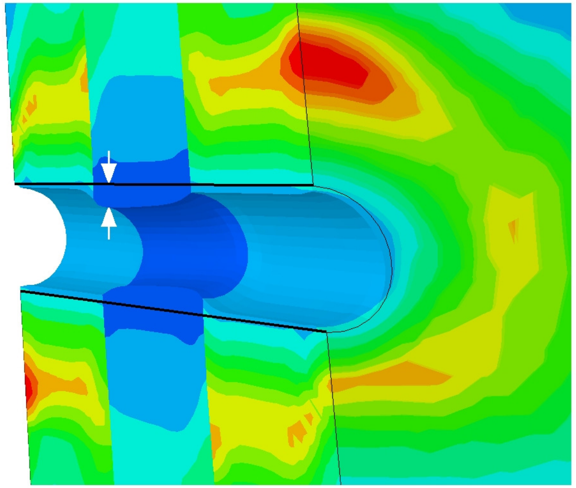
Deformation in the central shale as a function of shale layer thickness.

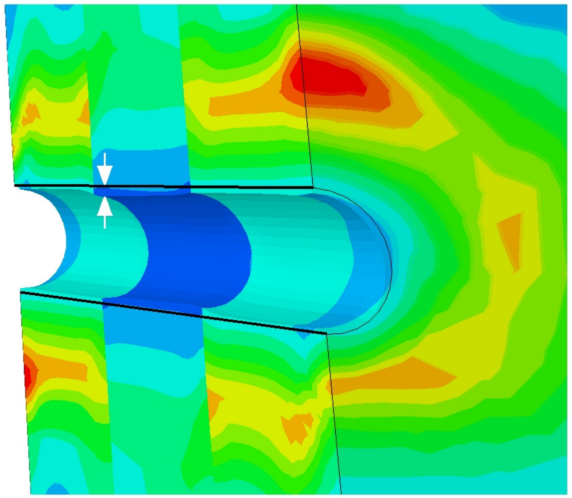
0.2m shale section	deformation 18mm (radially)	17% deformation
1m shale section	deformation 32mm (radially)	29% deformation
1m shale with 5-1/2" ESS	deformation 22.9mm (radially)	21% deformation ✗
1m shale with 7" ESS	deformation 17.2mm (radially)	16% deformation ✓

0.2m shale section

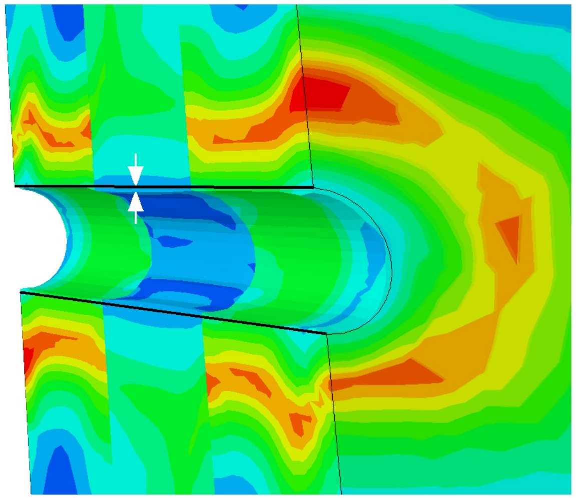


1m shale section



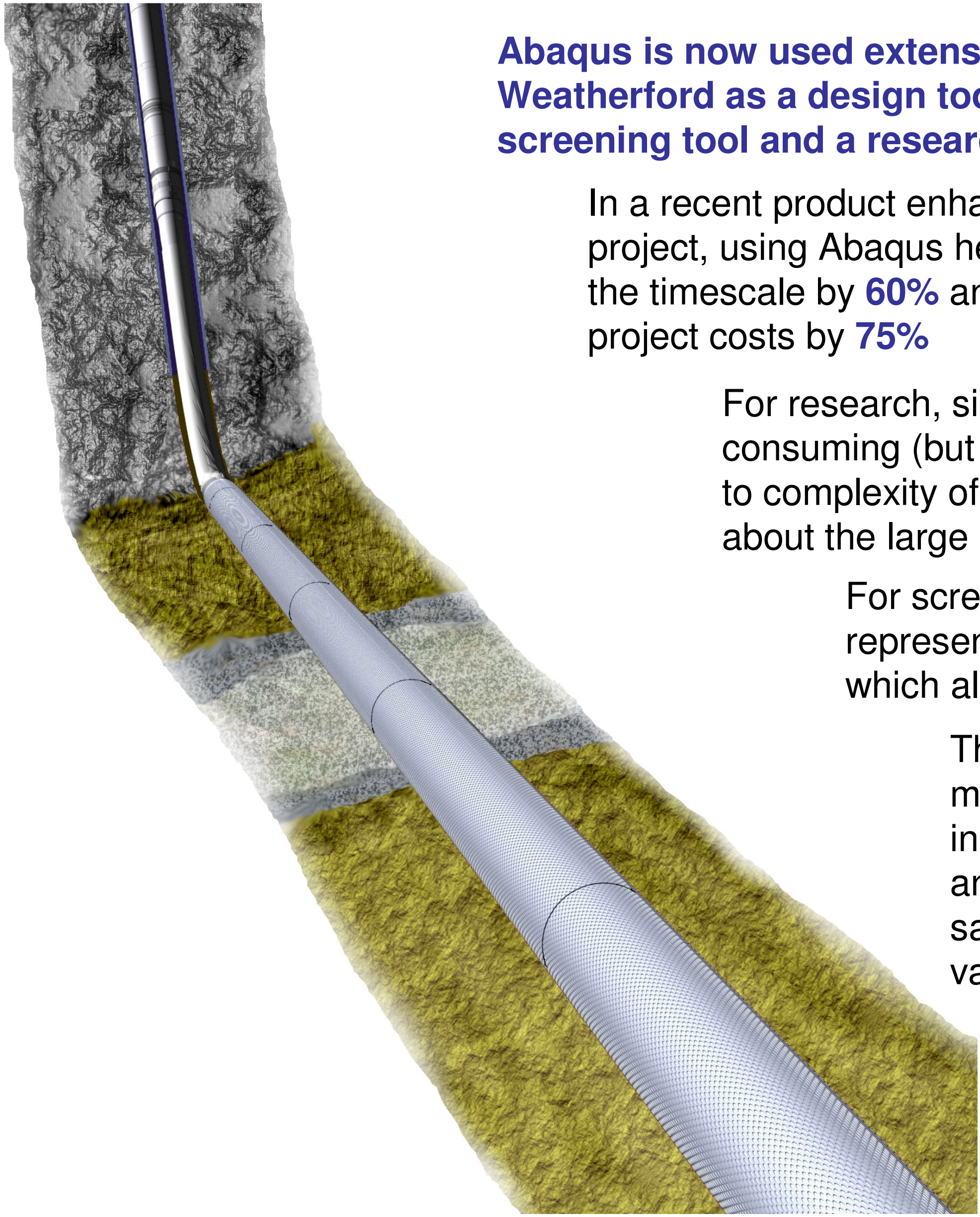


1m shale w/ 5-1/2" ESS (not shown)



1m shale w/ 7" ESS (not shown)

Conclusions



Abaqus is now used extensively within Weatherford as a design tool, as an application screening tool and a research tool.

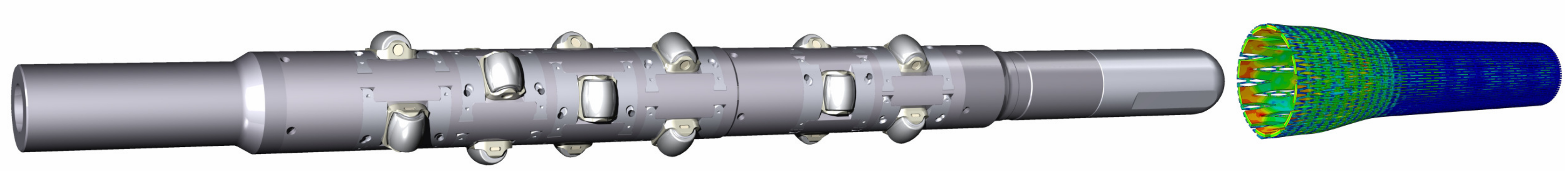
In a recent product enhancement project, using Abaqus helped reduce the timescale by **60%** and reduced project costs by **75%**

For research, simulations can be time consuming (but worthwhile for accuracy) due to complexity of the structure, which brings about the large number of mesh elements.

For screening of applications, a simplified representation of the ESS has been developed which allows for results to be produced very rapidly.

The equivalent ESS has been used to model more complex well architectures such as an inclined well crossing multiple layers. This has answered such questions as what happens at sand/shale interfaces and how deformation varies with shale layer thickness.

Weatherford®



Thank you for your attention

Please feel free to ask any questions