ANSYS solutions for Drilling and Completion

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Introduction

Drilling for oil is “boring”

Very harsh environments

Need to get things right

• Equipment design and reliability
• Fluid mechanics
• Electro-mechanical
• Asset management
Problems of Interest

Structural analysis
• Geotechnical engineering
• Vibration of drill strings
• Reliability of equipment
• Fatigue
• Hydraulic fracturing

Fluid mechanics
• Non-Newtonian flow
• Multiphase flow in a porous media
• Proppant transport
• Erosion of tools
Can we determine the local tectonic stress orientation before drilling?

To align horizontal well path parallel to the least principal stress axis
  – Ensures borehole stability
  – Ensures Optimal Fracture design
  – Secondary and tertiary recovery

World stress map project
Local stress orientations near faults can be different

Stress and displacement based boundary conditions changed to match the local stress orientations and magnitude.

Calibrated with a dug well.

Comparison between open fractures versus those predicted using ANSYS

This methodology has been validated by Andreas Henk, Univ Fredburg, Germany
Reliability of Drilling Process

Ensuring high reliability of all components

- Drill bit
- Drill string
- Casings
- Derrick
- Logging while drilling.
Drill Bit Design

Challenges
• Reliable cutting operations in harsh environments
• Rapid product development cycle
• Efficiency of cuttings removal
• Nozzle design plays a major role in cuttings removal
• Measurements and model visualizations are difficult and expensive

Contours of shear stress in the cone (left) and at the bottom (right).

ANSYS CAE Solutions
• Detailed information for the flow field and shear rate characteristics, indicating effective drilling mud removal
• Optimization
• Erosion prediction
• Understanding of cutting stresses
• Ability to design for torque related mechanical stresses

Tricone Drill Bit

Some images courtesy of Hughes Christenson & Pluere
Modeling Mud

Mud used to drive the drill, remove cuttings, cool and lubricate drill string, maintain well pressure and provide telemetry

Non-Newtonian fluid with particulates

Highly erosive environment
  • Components can quickly wear out

Need to minimize erosion
Drill Surface Cleaning

- Drill surface shear
- Flow pathlines

- Highlights regions with poor flushing
- May imply build-up of cuttings on bit
Stagnation Regions
Stress on the teeth

- Extra sections added to give friction body force on cutting surfaces
- Distortion of bit most evident on end of the thinner (unsupported) teeth
Lateral vibration can cause fatigue failure, excessive wear, and MWD tool failures.

Results from drill collar eccentricity

Understand effective length of string

Modal analysis to understand natural models and frequencies
Modeling Drill String Behavior

CAE can help to minimize excessive lateral displacement of Drill String

• Determining the free length of the Drillstring
• Determining lateral natural modes and frequencies of the effective Drillstring
• Identifying Large bending stress point in the BHA and other parts
• Generating lateral displacement trajectories at various locations
Wall Functions for Porous Media

Fluid flow in bore holes
Fluid flow along a porous wall
Use of wall functions recommended for wall boundary conditions
The porous media model can be used for a wide variety of problems, including:

- flows through packed beds
- perforated plates
- flow distributors
- tube banks
- rock formations

In porous zones, pressure loss in the flow is determined via user inputs of resistance coefficients.

In laminar flows through porous media, the pressure drop is typically proportional to velocity and/or $velocity^2$. 
Case Study

The Case
- Heterogeneous-layered oil reservoir
- Reservoir pressure $2.7 \times 10^7$ Pa (~3916 psi)
- Reservoir temperature 90°C (~194 °F)
- Density ~827 kg/m$^3$ & Viscosity ~0.0025 kg/m s

The Objective
- Selecting the optimum well drainage architecture using detailed near-wellbore modelling

The Options
- Vertical well with propped fracture & perforations
- Deviated well with propped fracture & perforations
Case Study: Vertical Well

Base case
- Perforations in S1 and S5 zones
- Poor drainage from the centre S3 zone
Case Study: Vertical Well

Perforations+ Fracture @ S3 layer

- Inflow capacity increased ~60% compared with the perforation only option
Case Study: Deviated Well

Perforations + S3 Fracture

- Well production is around 20% to 30% less than expected for the vertical well
Perforation helps create a hole in the casing through the cement and into the formation to form a channel for the oil and gas to flow from the producing formation into the wellbore.

**Purposes of Perforation**

- Creating a channel between the pay zone and the wellbore.
- Cause oil and gas to flow to the wellbore easily.
- Future stimulation. Example: Hydraulic fracturing
Jet Perforation

It uses shaped charges contained in a perforating gun assembly.

Gun assembly is placed in wireline, tubing or coiled tubing, depending on the application and the wellbore conditions.

High-pressure jet will penetrates the casing or liner to shoot into the reservoir formation to form channels.
Jet perforation design challenges

The dynamic interactions between the explosive, explosive products, base plate, confinement and liner present a challenging problem.

The liner undergoes severe, yet controlled, plastic deformation without breaking.

The jet path is very sensitive to the explosively driven loading pressures.
ProE CAD Model of Perforating Gun Imported into Workbench

ProE CAD Model of Perforating Gun Imported into Workbench

Showing Liner Only

Single Shaped Charge Cross-Section
Single Shaped Charge Model and Jet Formation Simulation

2D Axisymmetric Shaped Charge Model set up

2D Shaped Charge Simulation of the Jet Formation (explosive not visible)

Courtesy of Schlumberger
2D Shaped Charge Jet Remapped into 3D

Top View

Side View

Iso View

3D Simulation of a section of the Penetrator Gun 6 jets (4 shown)

Courtesy of Schlumberger
Shape Charge Jet penetrates Rock

Shear Damage: Damage is assumed to accumulate due to inelastic deviatoric straining (shear induced cracking) using the relationships

\[ D = \sum \frac{\Delta \varepsilon_{pl}}{\varepsilon_{pl\text{,failure}}} \]
Drilling and Completion has several challenges

- Harsh and remote environment
- Several components that need to work seamlessly in this harsh environment.

CAE can help
- Analyze the behavior of your components in this harsh and often remote environment