'Killer apps' of Abaqus in the Offshore Industry Max Leadley-Brown Dassault Systèmes

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SIMULIA is the Dassault Systèmes brand for realistic simulation

- · Vision: "Make simulation an integral business practice"
- Mission: "Be the leading provider of simulation solutions for engineering and scientific simulation"

Provide Realistic Simulation solutions for all industries







Sampling of Oil & Gas Customers

ExonMobil. bp StatoilHydro Taking on the world's toughest energy challenges." Saipem Schlumberger Eni EL PETROBRAS Technip subsea7 BAKER HUGHES -FMC **Aker**Solutions[®] HALLIBURTON Unleash the energy.™ ĴÅ jp kenn MANAGING RISK DN STRESS ENGINEERING ERVICES INC.



Industry-leading Simulation Technology

Comprehensive Technology

- Complete linear & nonlinear, implicit & explicit capabilities
- Multiphysics analysis including thermal, thermal-stress, pore pressure-stress etc.
- Wide-range of load types including wave, buoyancy, current, and wind loading

Complex materials

- Rubber, plastics, metals, soils, composites etc.
- Sophisticated contact, fracture, and failure
- Impact and dynamic events

Element technology

- Shells, beams, pipes, solids etc.
- Special purpose elements for pipe-in-pipe and pipe-soil interactions

High-performance parallel solvers







Offshore Applications





Reservoir Geomechanics

Application

• Determine subsidence and compaction as a function of hydrocarbon extraction

Why Abaqus Unified FEA?

- Coupled pore pressure-displacement solutions
- Element technology
- Library of soil material properties
- Damage and failure modeling
- User-defined extensions
 - Materials, elements, loads, etc.
- Contact
- Submodeling
- High performance parallel execution

Benefits

 Improve estimates of hydrocarbon production and avoid well bore failures



Courtesy: S. Mantica, G.Capasso & S.Monaco , eni E&P



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Analysis time [hrs]

4

2

4



Hydraulic Fracture

Application

 Simulate effects of hydraulic fracture on hydrocarbon production

Why Abaqus Unified FEA?

- Special-purpose cohesive elements with pore pressure degrees of freedom to model fractured surface
 - Specify tangential and normal flow
- Fully coupled pore pressure-displacement procedure using coupled pore pressure-displacement elements
- Good library of material properties, together with failure modeling
- User subroutines for using advanced and/or proprietary technology

Benefits

 Assess value of hydraulic fracture and use appropriate fracing technology



Hydraulically induced fracture near a well bore



Potential of XFEM technology in the





 Design well casings taking into account cyclic thermal loads and formation movements

Why Abaqus Unified FEA?

- Coupled thermal-stress analysis
- · Material models for metals and soil
- Fully coupled pore pressure-displacement solutions
- User-defined extensions

Benefits

 Reduce casing failures especially for Cyclic Steam Stimulation (CSS), Steam Assisted Gravity Drainage (SAGD), and other (thermal) secondary extraction methods



Figure 11. Casing lateral displacement and curvature caused by formation shear movement.

Courtesy: C-FER (SCC 2008)





Downhole Expandable Tubulars

Maximizes contact pressure: **200%** over pre-existing BR-Cone

Minimizes hoop stress (greatest negative hoop stress): **202%** over pre-existing BR-Cone

Improved thread engagement: **25%** better than BR-Cone

Minimizes expansion force: 10% less than BR-Cone

Recent Test Results: The Post-expanded connection held 5750 psi gas



Original cone: Developed over years of testing



Opti-cone: Totally free of potential fracture

"...we now can attack a market that no one has been able to until now: High-torque, gas-tight expanded connections."

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2010 SIMULIA Customer Conference, Jeff Williams, Baker Hughes



Sand Production

Application

 Estimate erosion and sand production as a function of hydrocarbon production

Why Abaqus Unified FEA?

- · Adaptive meshing with advection
- Solution mapping
- User subroutines for user-defined erosion criteria
- Fully coupled pore pressure-displacement solutions using coupled pore pressuredisplacement elements
- Element failure and deletion capabilities





Erosion of material (sand production) in an oil wellbore

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Benefits

• Determine appropriate sand control techniques with greater confidence



• Design and evaluate all aspects of Expandable Sand Screens (ESS®), from installation to operation in a variety of applications/reservoir conditions.

Why Abaqus Unified FEA?

- Most advanced FEA tool for realistic simulation accounting for all nonlinearities
- Geometry import from a variety of CAD tools and formats
- Extensive nonlinear material modeling for different types of rock and soil
- Sophisticated and yet very easy to use "general" contact capabilities to handle even the most complex contact conditions
- Abaqus/Explicit for simulating nonlinear dynamic events

Benefits

 Develop enhanced and new ESS designs with substantial cost savings



Courtesy: Weatherford







 Helical Buckling of Coiled Tubing in Directional Oil Wellbores

Why Abaqus Unified FEA?

- Model actual wellbore geometry and coiled tubing/drill pipe
- Include all nonlinearities, such as friction and contact
- Collection of analysis techniques for predicting buckling and post-buckling behavior

Helical buckling of coiled tubing

Benefits

 Potentially prevent expensive consequences of helical buckling using insights from simulations







Offshore Platforms

Application

 Assess response of offshore platforms under different loading conditions

Why Abaqus Unified FEA?

- Abaqus/Aqua for wave and wind loads
- Beams, shells, and constraints to accurately represent the structures
- Implicit and explicit dynamics for different loading conditions
- Thermal stress assessments to evaluate fire accidents

Benefits

 Assess and improve strength, stability, and safety of offshore structures for different loading conditions, including accidental impacts





Courtesy: Horton Deepwater





 Assess effect of deepwater umbilical installation process on umbilical behavior

Why Abaqus Unified FEA?

- Full 3D modeling capability, including scripting for automating model generation.
- Easy-to-use and yet very sophisticated "general" contact capability
- Combination of Abaqus/Explicit and Abaqus/Standard
- Element library with shells, solids, and rigid elements
- High performance parallel computing

Benefits

• Improve durability of deepsea umbilicals with greater upfront confidence in designs







Composite Pipelines

Application

 Assess failure modes and progression of failure in composite pipelines for various loads

Why Abaqus Unified FEA?

- Comprehensive composites simulation capabilities
- Combination of Abaqus/Standard and Abaqus/Explicit for different loading and operating conditions.
- Model change to simulate different conditions of the pipe
- High performance parallel solutions to minimize run times

Benefits

 Develop an all-composite pipe that can withstand the greater external hydrostatic pressures, higher internal wellhead pressures, and temperature extremes that accompany deepwater work



Courtesy: DeepFlex







Thermal Management

Application

- Estimate peak temperatures of umbilicals within a riser due to higher temperatures in production flowlines
- Estimate temperature drop in deepwater pipelines during no-flow conditions

Why Abaqus Unified FEA?

- 2D, Axisymmetric, and 3D heat transfer capabilities, including thermal contact
- Radiation heat transfer
- FSI for coupling heat transfer between fluid flow and structure

Benefits

- Develop cost-effective cooling solution for umbilicals
- Develop insulation to maintain pipeline flow assurance under extreme operational conditions & upsets





Courtesy: Technip





Threaded Connectors

Application

Determine failure mechanism of Threaded
Joint

Why Abaqus Unified FEA?

- Accurate contact Pressure
- Fluid pressure penetration
- Axisymmetric or 3D modeling as required
- Specialized elements axisymmetric and cylindrical elements

Benefits

 Improve designs and develop solutions for higher pressure connections







Sealing with Rubber Components

Application

· Insertion analysis of a shaft seal

Why Abaqus Unified FEA?

- Easy and accurate modeling of contact between various parts
- Nonlinear material models for rubber-like materials
- Large deformation analysis, including using coupled Eulerian-Lagrangian method
- Static or dynamic analyses

Benefits

Improved reliability and confidence in seal integrity



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Subsea Pipelines

Application

• Assess if the expansion from thermal and internal pressure loads will overload the PLETs or jumpers and/or will cause pipeline to buckle.

Why Abaqus Unified FEA?

- Include complex 3D geometry of seabed profiles in nonlinear contact analysis
- Nonlinear pipe-soil interaction behavior with friction models, including option of user defined friction models
- Element technology including pipes and connector elements
- Option of static analysis with stabilization or dynamic analysis to capture buckling behavior
- Thermal effects

Benefits

- Improved pipeline integrity taking into account shutdown/startup cycles
- Plan for buckle control measures to control fatigue damage





Courtesy: Technip







 Assess the integrity of spudcan foundations taking into account installation procedure and operational loads

Why Abaqus Unified FEA?

- Coupled Eulerian Lagrangian capability to capture soil-structure interactions accurately
- Extensive nonlinear material modeling for different types of soil.
- General contact to easily setup all contact interactions.
- Scalable parallel performance on many cores.

Benefits

Improve stability of offshore structures









 Iceberg gouging of sea floor near buried arctic oil pipelines

Why Abaqus Unified FEA?

- Coupled Eulerian Lagrangian capability to capture ice-soil-structure interactions accurately
- Extensive nonlinear material modeling for different types of soil.
- General contact to easily setup all contact interactions.
- Scalable parallel performance on many cores.

ABRIE Courtesy: JP Kenny

Benefits

• Optimize required pipeline burial depth for safe operations in the arctic ecosystem



New Features in Abaqus

<u>Abaqus</u> <u>Topology</u> <u>Optimization</u> <u>Module</u>: ATOM

- Provides topology & shape optimization
- Nonlinear Analysis
- Accounts for manufacturing restrictions
- Export results to CAD

Shape optimization moves nodes









Smoothed Particle Hydrodynamics

- Mesh-free Lagrangian method
- Particle connectivity is dynamic
- Suitable for modeling extreme deformation and fluid flow







Coupled Thermal-Electrical-Structural

Extension of thermal-electrical procedure with structural
Conductivity depends on separation and contact pressure





Courtesy: Technip







NDE-FEA links

- Use combination of scanning mesh building and XFEM for life assessment
- Isight to perform probabilistic assessments





(courtesy of Simpleware)

