Agenda

- Introduction to SwRI
- Project Overview
- Project Status
- Overview of Tasks
- Example Results
- Simulation Database Tool
SwRI Introduction

- SwRI is an independent, nonprofit applied R&D organization headquartered in San Antonio, TX
- Perform contract research for government and corporate clients
- SwRI is:
  - *Independent* – we do not compete with our clients
  - *Unbiased* – we do not have shareholders or stock
  - Perform work to maximize the benefit to the customer – novel intellectual property agreements
- SwRI facts:
  - Founded in 1947 by an oilfield businessman, Tom Slick, Jr.
  - Ten technical operating divisions with a staff of approximately 2,700
  - $560 M revenue in FY2016
  - 38 R&D 100 awards
Operational Characteristics

• Applied RDT&E Services
• Revenue from Contracts
• Physical Sciences & Engineering
• Broad Technological Base
• Capital-Intensive Operation
• Internal Research Program
Project Overview - Objectives

- Provide guidance to BSEE on simulation methods that combine mechanical (FEA) and fluids (CFD) analyses to better understand the effects of fluid-structure interactions during BOP blind shear ram closure.
- Develop an extensible software tool that will allow BSEE to compare anticipated operating environments and conditions with a database of previous analysis results.

This project focused on the operation of drill pipe shear rams.
Project Overview - Approach

- Research different methods that may be used to combine finite element analysis (FEA) and computational fluid dynamics (CFD) simulations to estimate the total shear ram force requirements under flowing conditions.

- From the different methods evaluated, use the methodology that provides the most fidelity, subject to computational efficiency, in order to examine a range of different equipment and operating conditions.

- Collect the simulation results into a database tool that allows the user to interpolate within the overall field of operating conditions.

Incoming Turbulent Flow
Project Overview

- **What is the project trying to accomplish?**
  - In the absence of experimental results of shear ram performance under extreme pressures and flowing conditions, what is the optimal simulation methodology for accounting for hydrodynamic effects?
  - Are there significant parameters that affect the influence of hydrodynamic forces on shear rams?
  - Can a database of results be compiled to build a software tool that will allow BSEE to compare third-party evaluations of equipment and conditions to new permit applications?

- **What is it not trying to accomplish?**
  - This is not a manufacturer/equipment comparison study.
  - It is acknowledged that this is not a full-physics representation of the problem, but rather a study to provide an extra level of physical fidelity that incorporates hydrodynamic effects.

- **What physical effects are included or not included?**
  - Only single-phase flow of crude oil up the annulus is considered. Multiphase flow of crude or drilling mud is not being simulated. Flow within the drill pipe is not being considered.
  - Sand, debris, solid matter, and potential erosion effects are not within the scope of this work.
  - Evaluation of shear ram deformation or failure is not within the scope of this work.
  - Evaluation of the hydraulic systems or their designs that apply pressure to the shear rams is not within the scope of this work.
  - Only drill pipe is being considered within the simulations and auxiliary tubing/cables or drill pipe connections are not included.
  - Off-center pipe and potential bowing/buckling/tension effects are not considered.
  - Potential operational characteristics, such as flow diversion away from the annulus, are not considered.
Project Tasks - Summary

- Task 1: Define Baseline Condition and Parameter Variations
- Task 2: Baseline Studies and Modeling Approach Assessment
- Task 3: Parametric Simulations
- Task 4: Database Tool Development

Note that this project is still underway and this presentation will focus on the project overview, scope, and approach. Details of the results shall be presented at a later date.
Task 1: Baseline Case Definition

- A baseline set of conditions was selected to perform the initial analysis of different simulation approaches in Task 2
- Conditions specified include:
  - Wellbore dimensions
  - Drill pipe specification
  - Shear ram geometry
  - Ram closing time
  - BOP depth
  - Well depth
  - Annular flow rate
  - Fluid properties
  - Flowing pressure and temperature
In Task 2, different methods for combining mechanical (FEA) and fluids (CFD) forces are investigated.

1-D well flow modeling was used to determine the conditions at the BOP stack and evaluate potential transient hydraulic pressure spikes.

A tiered approach to evaluating fluid-structure interaction (FSI) simulation methodologies was investigated:

- Tier 1: FEA Only
- Tier 2: CFD/FEA Linear Superposition
- Tier 3: Lock-Step Coupled CFD/FEA
- Tier 4: Dynamically-Coupled CFD/FEA
1. Use 1-D flow model (OLGA, SINDA/FLUINT) to compute the hydrostatic pressure, temperature, and fluid properties at the BOP. Also, the well modeling was used to assess the annular flow rate through the BOP as a function of area open to flow as the shear rams close.

2. FEA (LS-DYNA) with a Johnson-Cook material model used to simulate the deformation and failure of the drill pipe as the rams are closed. Mechanical shearing forces are computed here.

3. Geometries from the FEA simulation are analyzed at discrete points in time (100%, 40%, 20%, 10%, and 5% of annulus flow area remaining).

4. CFD (Fluent) used to compute the flow field around the ram and the hydrodynamic pressure on the ram faces.

Diagram:
- Hydrostatic Force
- Hydrodynamic Force
- Mechanical Shearing Force
- Total Ram Force
Representative Simulation

Ram geometry is purely for demonstration and does not reflect any specific OEM.
Representative Simulation

Ram geometry is purely for demonstration and does not reflect any specific OEM
Representative Simulation

- Mechanical shearing force from FEA simulations represents the starting point for all analyses
- From here, different methods of combining the FEA simulations with CFD simulations have been explored
Representative Simulation

Schematic of Fluid Domain of Interest

Flow Stream Lines

Incoming Turbulent Flow

Local pressure forces on ram surfaces
Verification and Validation Efforts

- Simulated experiments reported in “Final Report 01 – BOP Stack Sequencing and Shear Ram Design,” MCS Kenny, 2013
  - Good agreement with measured shear forces observed
  - Shearing of 3-1/2”, 13.3 lb/ft, S-135 drill pipe with 13 5/8” Cameron rams
  - Note that the simulation model and S-135 drill pipe material model were independently developed and not taken from the 2013 report
- Additional shearing simulations of 6 5/8”, 50 lb/ft, S-135 pipe have also been compared with OEM test data (not shown here)
Verification and Validation Efforts

- Significant effort was made to verify the proper definition of the numerical parameters used in the mechanical and fluids simulations

- Numerical and physical parameters examined include:
  - FEA and CFD grid resolutions
  - Drill pipe boundary conditions
  - Computational domain size
  - Drill pipe material model
  - Material-on-material contact detection algorithms
  - Surface-to-surface friction
  - Turbulence model effects
Comparison of Approximate and OEM Ram Performance

- Simulations have been performed using approximated ram geometries and physically accurate ram geometries
- Different shearing dynamics may be observed depending upon subtle changes in blade geometry
Task 3: Parameter Variation Study

- Variations on the baseline case have been simulated to determine potential affects of hydrodynamic forces under different conditions
  - 3 different OEM ram geometries
  - 2 different ram closing speeds
  - 2 different annular flow rates
  - 3 different flowing pressures
  - 1 different fluid property
  - 2 different tubing geometries
BOP Ram Force Database Tool

Subsea BOP Stack Shear/Seal Database

New Ram Manufacturer

Enter a new Ram Manufacturer:  

Save  Cancel  View List

New Ram Model

Enter a new Ram Model:

Save  Cancel  View List

Baseline SwRI

Ram Model: N/A
Flow Rate (bpd): 100,000
Tubing Size (in): 6.625
Closing Time (s): 11.2
Flowing Pressure (psi): 11,000
Fluid Density (kg/m³): 622.8
API Gravity: 35
Gas-Oil Ratio (scf/stb): 1,397
Wellbore Diameter (in): 18.75
Maximum Tidal Requirements

Form View

Programs

3:59 PM
7/1/2017
Thank You

Thanks for Your Attention

Any Questions?