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Ensuring Real-Time Deepwater Well Performance: Physics-Based Well Technical Limits

Maintaining well integrity during both the drilling and operating phases of deepwater wells is critical for economic development of oil and gas resources. ExxonMobil has developed physics-based technologies that have been applied in the planning stages of a field development as well as in real-time, resulting in substantial cost savings. Real-time well performance monitoring is critical to ensure drilling, completion and production operations are conducted in a manner to achieve optimum well performance.

Real-Time Drilling Technology

To help plan challenging wells, ExxonMobil drilling staff use a quantitative "Engineered Well Design" approach that combines a detailed understanding of the physics of wellbore mechanics during drilling with quantitative risk analysis (QRA) technology. Proprietary physics-based models are used to address key drilling issues such as well control, wellbore stability, hydraulics, hole cleaning, lost returns, differential pressure sticking, and torque and drag.

During the planning phase, the key input data come from offset wells, seismic data, and/or geologic basin models. The QRA technology accounts for uncertainty in the input data and integrates these physics-based models, as shown in Figure 1. The figure shows the probability of drilling success for a particular interval as a function of mud weight and flow rate. Optimum drilling parameters that increase the probability of success are determined for each drilling interval. The cost of drilling is then incorporated to facilitate optimization of the overall design while minimizing cost.

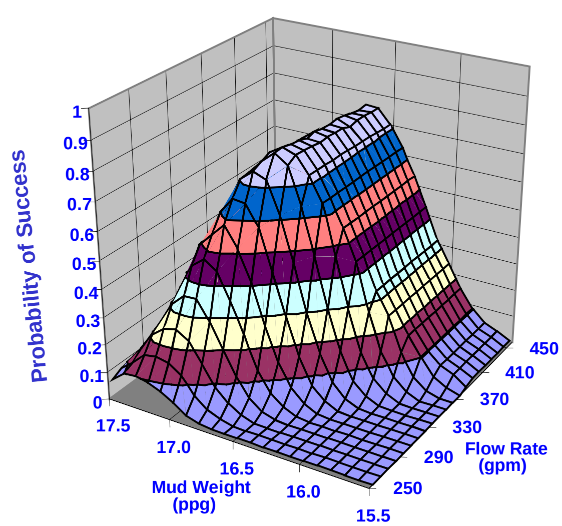

Figure 1. Probability of Drilling Success as a Function of Mud Weight and Flow Rate

While drilling the well, real-time data are used to update the engineering models and the QRA analysis. Real-time data acquisition, such as pressure while drilling (PWD), mud logging and dielectric constant cuttings analysis (a proprietary method for shale strength determination), are used to update the models. The models are then used to suggest changes in controllable drilling parameters, including casing setting depths. This approach of physics-based modeling, QRA, and real-time updating has been used successfully by ExxonMobil worldwide, including in the drilling of deepwater wells offshore West Africa, in the Gulf of Mexico, and in the Caspian Sea. Specific examples are given in the presentation.

Real-Time Well Productivity

Ensuring long-term integrity and performance of a well is essential to economic development of a field. ExxonMobil has therefore developed technologies that addresses completion and production issues such as tubular design, annular pressure buildup, wellhead growth, connections evaluation, reservoir compaction, sand production and flow impairment.

ExxonMobil uses physics-based production models to account for complex well loads encountered in deepwater production. This probabilistic tubular design method, ExxonMobil Load and Resistance Factor Design (EMLRFD), has been extensively used to determine the reliability of tubulars and reduce well cost. The method was developed using data from thousands of pipe inspections and load data from hundreds of instrumented drill wells. Detailed flow modeling and multi-string force balances have been combined with the probabilistic tubular design methods to evaluate the effect of annular pressure buildup and wellhead growth. Mitigation techniques for annular pressure buildup have also been designed and evaluated using finite element analysis and full-scale physical testing.

ExxonMobil's Connections Evaluation Program combines non-linear finite-element analysis with full scale physical testing (see Figure 2). Rigorous physical tests (including make-and-breaks, gas sealability, structural failure, internal quench, collapse tests and thermal cycle tests) are performed when evaluating a tubular connection. The physical test results are used to validate the finite element models. A performance envelope for each connection is then developed, from the combination of the physical test results and rigorous computer modeling, which can then be compared to field loads.

Finite element analysis is also used to determine the potential for wellbore failure as the result of reservoir compaction. ExxonMobil has developed the capability to establish a well operability limit that defines the boundary between safe well production operation and failure due to reservoir depletion and/or drawdown. The model is calibrated using core and log data. Throughout the life of the well, any changes in the operating parameters (i.e., drawdown and/or depletion) can then be compared to the well operability limit to determine the potential for well failure (see Figure 3). A rapid response surface version of this physics-based technology makes it possible to manage the performance of the well in real-time.

Determination of the potential for sand production early in the planning stages of the development of a field is essential to select the appropriate completion. If not anticipated, or planned for, sand production can result in significant loss of revenue due to increase in maintenance and workover operations, damage to equipment, and/or loss of productivity. ExxonMobil has developed the technology to determine the potential for sand production using core data, log data and finite element analysis. This technology has been applied to many fields to help determine the completion and production options that result in optimum well performance.

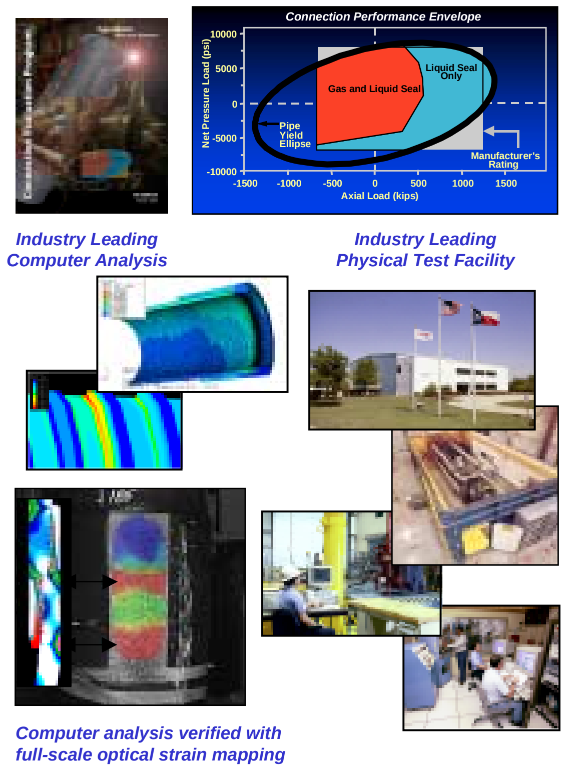

Figure 2. ExxonMobil's Connection Evaluation Program

Because understanding the potential for flow impairment is critical to predicting or evaluating well performance, ExxonMobil has developed technologies that characterize the impact of drilling, completion, and production operations on well productivity. These effects are evaluated through an integrated program of laboratory testing and full physics-based numerical modeling. For example, small-scale and full-scale laboratory flow tests are used to quantify damaging effects of various drilling or completion fluids. These test results are coupled with numerical models to quantify the impact of completion design on flow impairment (including effects such as perforation geometry and gravel pack design), which in turn are coupled with geomechanical models to quantify long-term flow impairment due to reservoir compaction effects. With a detailed understanding of flow impairment effects, educated decisions can be made from the planning process to surveillance operations, to help optimize well economics.

Real-time monitoring of downhole gauge data provides an opportunity to further optimize wellbore production and injector performance. ExxonMobil has developed tools that provide an efficient method for capturing changes in production performance from continuous downhole gauge data. Analysis of the field data combined with modeling capabilities can be used to optimize well performance. For example, Figure 4 shows the performance of a well before and after the well was stimulated. Monitoring of the production data indicated a significant decrease in production with an increase in drawdown (as seen on the left side of Figure 4). A stimulation program was developed, which included extensive laboratory testing. Once the stimulation treatment was performed, production logs were run to verify the effectiveness of the treatment. Production data monitoring after the stimulation (as shown in Figure 4) confirmed success of the treatment.

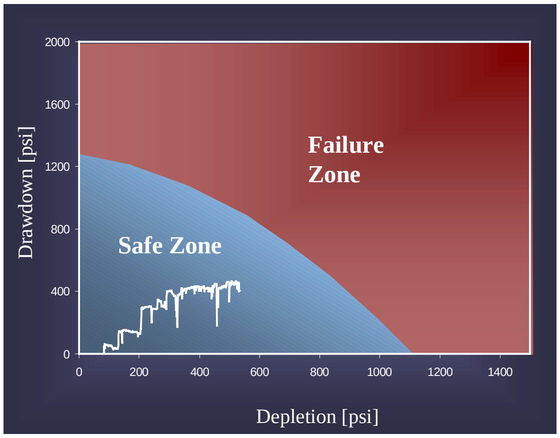

Figure 3. Real-time Monitoring of Well Failure Potential.

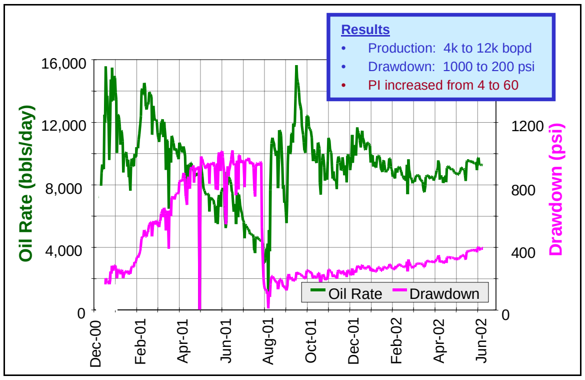

Figure 4. Production Rate Pre- and Post-Stimulation.

Summary

The application of physics-based technologies during the planning stages of a deepwater development and further optimization in real-time is essential to ensure economic developments of oil and gas resources. Several examples that demonstrate ExxonMobil's success in applying its physics-based drilling and production technologies are given in the presentation.