Kick precursor analysis improves drilling risk management

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As the industry continues to innovate, moving into ultra-deepwater and other frontier areas, inherent risks will be myriad and diverse. Although major accidents such as blowouts, fire/explosion or complete loss of structural integrity are rare events in the offshore industry, unforeseen incidents can occur. It is mission-critical to find better ways to manage major accident risk on board offshore units to minimize potential hazards.

Classification societies, operators, drilling contractors, and the agencies regulating offshore operations are working in tandem to raise the safety bar by considering more comprehensive risk management and accident prevention plans. Supplemental to the measures already in place and advancing alongside technology, a research and development (R&D) project is under way to validate a new risk management approach that can detect precursors to major events so that the probability of a major offshore accident can be reduced.

Precursors are operating events (deviations from the norm) that could result in a high-severity consequence when occurring in conjunction with one or more postulated events. Precursors can include incidents, near-misses, and unusual system conditions encountered during routine operations, inspections, testing, and engineering evaluations, as well as operational and organizational matters.

To address these issues, ABS has been performing a precursor analysis project. This project is planned in two parts. Phase A focuses on the precursors to a well kick, and Phase B involves evaluating post-kick precursors leading to a blowout. Phase A of the project has successfully identified kick precursors and related risk influencing factors (RIF) that, dependent on their state, influence the probability of a precursor to occur. A risk model also has been developed to analyze the influence of the precursors on kick frequency.

ASP presents a proactive risk management approach to identify critical precursors and RIFs. The consequence of interest (COI) in this case is a kick.

Deepwater regulatory compliance

Classification societies are an integral part of the verification process for global offshore safety regimes to promote the security of life, offshore units and the natural environment by establishing Rules and Guides and assisting regulatory bodies with the development of acceptance criteria.

Following the Macondo incident in the US Gulf of Mexico (GoM), operators are required to comply with recently updated regulations. Significant federal regulatory mandates 30 CFR Part 250 and API Recommended Practice 75 require the development, implementation and maintenance of Safety and Environmental Management Systems (SEMS).

The industry-sponsored Center for Offshore Safety (COS) was established to promote the highest level of offshore safety in the deepwater GoM and address compliance with API Recommended Practice 75. As part of the wholly owned ABS Group of Companies, ABS Quality Evaluations Inc. (QE) has served on the COS audit committee to assist in developing guidelines used for SEMS audits. ABS QE has performed audits for multiple entities, including oil majors operating in the GoM.

Operators using BOPs also must demonstrate to US regulators that there are adequate containment resources aboard the structure that can be deployed in the event of a blowout or other major hazard. In 2011, the Bureau of Safety and Environmental Enforcement (BSEE) contracted ABS and ABS Consulting to study the current practices for BOP maintenance, inspection, and testing and to make recommendations for industry best practices.

Classification societies need to work closely with industry, the US Coast Guard and BSEE to strengthen regulations in line with the goal of improving operational safety on offshore facilities and equipment, limiting environmental impacts and, ultimately, preserving human life.

Proactive risk management

Offshore incident investigations frequently reveal that during the initial stages of a developing accident, there are prior indicators, signals, and alerts. If properly detected and managed, these accident sequence precursor (ASP) indicators provide crews with critical information that can help prevent accident progression that could result in catastrophic consequences.

Based in part on programs used by the US National Aeronautic and Space Administration (NASA) and the US Nuclear Regulatory Commission programs, this proactive risk management approach is providing the framework for creating an ASP program within the offshore industry. A joint research effort between ABS, a leading classification service provider to the offshore industry, and Safetec Nordic AS, an ABS Group company providing integrated risk and asset management services for offshore oil and gas, is using this methodology to develop a risk model by coupling historical operational experience with risk analyses.

In the ASP approach, candidate precursors (screened-in operating events) undergo a probabilistic analysis to determine the criticality of deviations from normal operating conditions. Once detected, risk control options are implemented. The risk significance

of the precursor is determined by mapping it onto a risk model to derive the conditional frequency of consequences of interest (COI), such as blowouts, fire/explosion, or structural failures.

Identifying kick precursors

Any operating event that initiates or influences the kick probability has the potential to be a candidate precursor to a kick. A range of operating events – technical, operational, and organizational – theoretically affects the potential for a kick.

Sources of operating events include near-miss reports on well integrity, management of change process documents reporting changes to equipment or operations or organization, mechanical integrity program findings regarding availability of rig critical equipment and maintenance backlogs, and classification society findings (i.e., structural/machinery review and survey).

The resource-intensive nature of precursor analysis demands the screening of operating events to identify high-risk precursors and to eliminate those considered "non-risk significant." These operating events are subjected to a qualitative criticality assessment and evaluated on their level of influence on the probability of a kick. If the event is deemed to have significant influence, it is considered as a candidate precursor. Causes considered to have marginal correspondence with kick potential that were screened out include:

- Drilling operations that are outside the design conditions for the rig and equipment
- Supply chain interruptions, such as a delay in supply of mud, cement, drilling equipment, or other safety critical elements that are necessary to maintain barriers
- Rig blackout with subsequent emergency generator failure
- Helicopter transport delay
- Information received by personnel involved in drilling operations that may cause distress.

Risk model for offshore drilling

The primary objective of the risk model is to determine the criticality of the candidate precursor and the need for implementing risk control options. For the purpose of probabilistic analysis, a risk model is developed using a fault tree structure constructed as a hierarchy of operating events/candidate precursors influencing kick frequency.

Included in the initial risk model are industry experience and the knowledge derived from accident investigation reports, including recent events such as the North Sea well control incident on Gullfaks C in 2010 and the Macondo accident in the Gulf of Mexico that year.

Due to the limited availability of historical data for annular failures, however, it is necessary to use an approach where probability of failure is weighted among the various branches of each node, starting at the top and moving downward.

The fault tree is constructed to show a particular kick as the result of a specific basic event. Each basic event is accompanied by RIFs that affect its probability, thereby affecting the kick frequency, such as "competence," "time pressure," and "seismic surveys." A preliminary set of 12 RIFs have been identified.

It is important to note that the extent to which the basic event frequency is affected by the total of the RIFs is limited. Each basic event also has an RIF independent weight, a fundamental part of its frequency that cannot be changed, regardless of RIF state. This RIF's independent weight is denoted as a percentage of the basic event's initial kick contribution.

There is a preset distribution showing the extent to which each RIF affects each basic event frequency. As an example, each RIF is given a score from A through E on a scale from 0.1 to 10.0. This scoring would be primarily based on input from company audits.

By applying the concept of RIFs, the trend of the specific blowout risk, whether it is increasing or decreasing, can be estimated by measuring the relative change in kick frequency from its initial value as the RIFs change state.

Methodology results

The risk model indicates that some of the most likely contributing precursors to a kick based on the basic event probabilities (initial kick contribution), when all RIFs are in an "acceptable" state or Grade "C," are:

- Mud weight underbalance or overbalance
- Encountering an unanticipated formation
- Formation breakdown from increased equivalent circulating density (ECD) pressure
- Instrument failure
- Unsatisfactory casing program
- Insufficient waiting on cement.

A sensitivity study carried out by setting the grade of one RIF from "A" to "E" while others remain unchanged determined that some of the most critical RIFs are:

- Competence
- Seismic surveys
- Drilling fluid program
- Procedures and operations planning
- Maintenance
- Work practice.

Work to date demonstrates that by improving the state of all RIFs from "C" to the "B" or "A" level, there is potential to reduce the probability of a kick by 50%.

Currently, the risk model is sensitive to relatively small changes in the model structure and associated weight distribution. Further analysis and development are ongoing to evaluate operating events that are not included in the present model because there are differences that would have to be considered when evaluating exploration or production drilling, or jackups drilling in shallow water and semisubmersibles working in deepwater. Evaluating different scenarios using the model will lead to more nuanced modeling with a greater ability to predict risk.

Further work

Phase B of the project is progressing with the post-kick precursors leading to a blowout identified along with the RIFs. A risk model has been developed as an event tree representing the event sequences with linked fault trees. The event tree developed is for an influx while drilling with the drillbit on bottom. Validation of the risk model with respect to assigned weights and sensitivity of the RIFs is ongoing.

RIFs for both pre-kick and post-kick precursors also have been tied into the relevant personnel group, such as "driller," "assistant driller," "tool pusher," "mud logger" and "onshore planner." Risk indicators to score both the pre-kick and post-kick precursors are being identified, with completion set for late 2013.

Looking ahead

Offshore operations are costly, and stakeholders are demanding assurances that problems can be controlled quickly and effectively. Progress has been made in applying ASP to offshore operations, but there is a need for an industry-wide effort to collect real-world precursor data and model testing before this methodology can be integrated into a daily risk management program.

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