Drilling problems: Techniques aim at improving drilling performance

IADC/SPE 59121

When Rock Mechanics Met Drilling: Effective Implementation of Real-Time Wellbore Stability Control

Real time wellbore stability and control provide recommendations on drilling parameters to optimise the drilling process and reduce the risk of unscheduled events or lost rig time caused by wellbore instability. The technique uses surface and downhole measurements, while drilling, to make regular updates to a model of the wellbore, and revise the drilling plan accordingly.

The real time wellbore stability process first generates a mechanical earth model from information obtained in offset wells together with field and regional data. The proposed well trajectory for the new well is projected into the mechanical earth model and a set of stability parameters is generated along the proposed well for a given initial drilling plan.

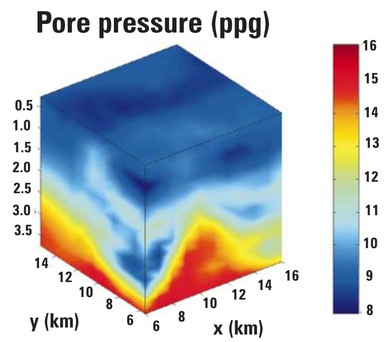
During drilling, real time measurements including LWD and MWD, surface mechanical measurements, and fluids and solids monitoring, are used to diagnose the state of the wellbore. Any significant hole instability is detected and a warning given to the driller. The existing state of the wellbore is compared to the model and any revision required to align the predicted with the detected state is made. This real time update of the mechanical model is then used to predict the future state of the wellbore, in front of and behind the bit for the given drilling plan. If the drilling plan can then be improved, a revision will be recommended; for instance a reduction in the rate of penetration, increase in mud weight, mud circulation and, if required, hole direction.

—I Bradford,
Schlumberger Cambridge Research, *et al*

IADC/SPE 59122

Predrill Pore Pressure Prediction Using Seismic Data

An accurate knowledge of formation pore pressure is a key requirement for the safe and economic drilling of deepwater wells, and enables optimum casing and mud design. In addition, a determination of pore pressure allows the effectiveness of seals, the sealing potential of faults and the hydraulic connectivity of the basin to be assessed.



IADC/SPE 59122: Pore pressure predictions are obtained using various methods of determining seismic interval velocities from prestack seismic data. The paper compares them using a deepwater Gulf of Mexico case study. The authors also recommend a velocity analysis approach suitable for pore pressure prediction.

In this paper, pore pressure predictions are obtained using various methods of determining seismic interval velocities from prestack seismic data. They are compared using a deep water Gulf of Mexico case study, and a velocity analysis approach suitable for pore pressure prediction is recommended. This is aimed at producing a pre-drill pore pressure cube from 3D seismic data, and uses seismic tomography to obtain an accurate velocity model. Seismic velocities obtained by conventional methods average the velocity over the seismic aperture and are therefore not suitable for pore pressure prediction in the presence of lateral variations, as may arise from the presence of dipping structures, lithology variations, salt layers of various thickness, fault blocks or variations in compaction and pore pressure. Reflection tomography gives improved spatial resolution of the seismic velocity field and thus allows a more reliable pre-drill pore pressure cube to be obtained.

—C M. Sayers and G M Johnson, Schlumberger Oilfield Services
–G Denyer, EEX Corp

IADC/SPE 59123

Real-Time Formation Integrity Tests Using Downhole Data

The rate of downhole pressure buildup is traditionally estimated from the standpipe pressure but can now be monitored directly with an annular pressure measurement. We discuss 2 methods that can be applied to give a real-time profile of leak-off test (LOT) and formation integrity tests (FIT).

The first method is a real-time FIT from a deepwater well in the Gulf of Mexico. The low flow rates used during an FIT/LOT preclude the use of traditional MWD systems to transmit data to the surface. However, with the use of a wireline coupling, downhole pressure was transmitted to surface in real-time, allowing the operator to simultaneously view the surface and downhole pressure build-up, and evaluate both the formation integrity and mud compressibility. The second method uses both surface and downhole data from a North Sea well. We describe an algorithm in which 2 downhole pressure points are used to calculate the hydrostatic and compressibility offsets between surface and downhole A complete LOT profile is then created at surface as soon as conventional pumping resumes.

—I Rezmer-Cooper,
Schlumberger Oilfield Services, *et al*

IADC/SPE 59124

Improving Drilling Performance and Detecting Formation Fracture

Developmental drilling on the Opukushi field in the Niger Delta region by the **Shell Petroleum Development Co** well engineering team has historically met with traumatic drilling conditions resulting from bore hole instability problems.

On the Opukushi 28 horizontal well, the operator drilled an 8 ½-in. hole section plagued with consistent hole problems. During one of the runs with a rotary assembly designed to clean the hole free of junk, a tight spot was encountered and the sequential reaming knocked off the brittle shale, causing the operator to increase mud weight to suppress the sloughing shale, believing that the shale was collapsing. The well began to take fluid and caused formation fracture in the sand zones. This led to severe loss of costly oil-based mud, and eventual rig shut down due to lack of enough mud required to drill ahead. Circulation was eventually totally lost in the water sands.

This paper descirbes teh Opukushi 28 horizontal experience, including log examples. It illustrates the relevant features that can be inferred from drilling-log data to improve subsequent drilling performance.

—C Onwuazo, Shell Petroleum Development Company Nigeria, *et al*

IADC/SPE 59125

Abnormal Pressure Detection and Wellbore Stability Evaluation in Carbonate Formations of East Sichuan, China

Pore pressure prediction and wellbore stability evaluation in carbonates have become a concern recently. That is why for fractured, gas-bearing carbonate formations in east Sichuan, China, we decided to work on an abnormal pressure detection method and a wellbore stability evaluation approach. Though a lot of effective methods have been developed for overpressure detection in sand/shale formations, pore pressure detection in carbonates is still a very tough job up to now. In this study, we developed an abnormal pressure detection method based on relationships between Poisson's ratio, the ratio of P-wave velocity to S-wave velocity and vertical effective stress.

—Q Li, Schlumberger Oilfield Services, *et al*

IADC/SPE 59126

Simultaneous Drill and Case Technology—Case Histories, Status and Options for Further Development

Over the last five years, typical Drilling Liner runs were carried out in applications where the target depth was just a few meters away, but impossible to reach. Drilling ahead caused hole collapse, losing the well, the drill string, and the BHA. Finally, the success of the entire well depended on drilling just a few meters ahead. The benefits of Drilling Liner technology have solved these problems in Norway and Indonesia. The technology enabled savings of up to US $1 million.

—D Hahn, N Froelich and G Stewart, Baker Hughes Inteq

IADC/SPE 59127 (ALTERNATE)

Differemtially Stuck Pipe: Early Diagnostic and Solution

This paper describes new concepts for the stuck mechanism due to differential pressure. This paper also describes early symptoms during drilling that are essential to detect the increasing risk of the string being stuck. New fluid tests are proposed in order to define, more realistically, the penetration characteristics of the drilling fluids in a permeable formation. It is demonstrated with several lab and field results that the current tests can lead to a wrong and dangerous conclusion. In light of these new concepts and test results, the paper presents the solutions that can dramatically reduce the risk of experiencing stuck pipe due to differential pressure. The paper finally shows some recent field results where the solution was adopted with huge improvement when compared to the traditional operations.

—H M Santos, Petrobrás

IADC/SPE 59128 (ALTERNATE)

The Mechanical Earth Model Concept and Its Application to High-risk Well Construction Projects

Well construction projects are becoming more technically and economically challenging as we push the barriers to achieve viable production opportunities. To complete complex wells safely, on time and within budget requires minimizing non-productive time associated with wellbore instability and unexpected pore pressure regimes. Building a mechanical earth model during well planning and revising it in real time has proven to be extremely valuable for minimizing unplanned well construction costs and focusing the team effort.

This paper will describe what a mechanical earth model is, how it is developed and refined while drilling. We will discuss sources of information and the multi-disciplinary team approach required to generate, revise and maintain an earth model.

—R Plumb and S T Edwards, Schlumberger-Holditch RT
—G A Pidcock, Schlumberger IPM

IADC/SPE 59129 (ALTERNATE)

Formation Chracterization of a Horizontal Well While Drilling: An On-Site Tool

When a well kicks while drilling, especially a horizontal well, evaluation of pore pressure and the corresponding kill mud density is of critical importance. This, however, is not straightforward problem as, upon shutting in the well, casing and drill pipe pressures vary with time. In this paper, we show how to mathematically model the pressure buildup with the limited information available at the time of an oil/gas kick in a horizontal well. It is demonstrated how the actual pressure buildup can be used for pore pressure (mud density) determination. Extensive simulations were carried out by coupling the reservoir and wellbore models. 3 cases (onshore and offshore) are described and analyzed in this paper.

—R G Samuel, Lanmark Graphics Corp

IADC/SPE 59130 (ALTERNATE)

Well Characterisation Procedures for Early Kick Detection

The fluid flow-back when pumps are shut down on a connection can derive from a number of sources: surface equipment drainage, fluid compressibility, thermal expansion, wellbore breathing and/or a fluid influx or kick. Well characterisation is the quantification of the fluid flow-back profile and volumes when pumps are shutdown in cased hole prior to drilling the interval. Through the comparison of these base curves with those determined in real-time during connections, rapid identification of any fluid influx or kick is possible. In this paper, well characterisation procedures to differentiate between normal flow-back rates and volumes for early kick detection are explained. Several case studies of deepwater Gulf of Mexio wells are discussed.

—M D Green, J Song and D Power, Baroid Corp

Zonal isolation: Enhancing cement placement downhole

IADC/SPE 59131

Improved Zone Isolation Using Sealants Before Primary Cementing Operations

Conformance treatments can allow for the sealing of problematic intervals prior to the primary cementing work and can alleviate potential well-control problems, can improve the success of primary cementing, and can prevent loss of isolation due to casing expansion and contraction during production pressure cycles. In essence, the formation itself becomes the zone isolation mechanism instead of relying totally on the cement sheath integrity.

The process of sealing problematic zones during the drilling phase involves the use of coiled tubing, a slow-rotating hydro-blasting device, and an appropriate sealant that is water-thin during placement and becomes an elastic polymer in-situ. An example of the process is presented for a 7 7/8-in. wellbore and a 13 1/2-in. wellbore.

—L E East, *et al*, Halliburton Energy Services

IADC/SPE 59132

New Cement Systems for Durable Zonal Isolation

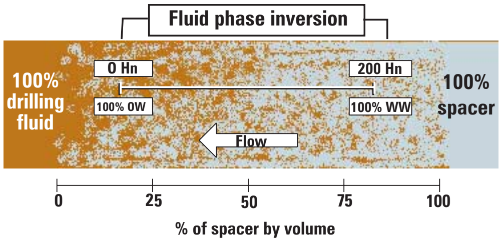
In this paper we will first present the analysis of various wells where we have determined the required cement mechanical and physical properties to avoid either cement failure or micro-annulus formation. In particular, we will demonstrate that flexible cement systems show good results concerning the necessary mechanical and physical properties in case of well temperature/pressure change. Moreover, the use of a cement that favours expansion to prevent the formation of a micro annulus is recommended. We will also show that cement expansion works better if the cement is flexible and has a low compressibility.

—S Le Roy-Delage, C I Baumgarte and B Vidick, Schlumberger Oilfield Services

IADC/SPE 59137

New Model of Pressure Reduction in Annulus During Primary Cementing

Gas migration after primary cementing that causes gas flow from the annulus can be a costly and dangerous problem.



IADC/SPE 59135: With simple instrumentation, operators can accurately determine the apparent wettability of spacers and preflushes used in cementing operations.

The major factor that initiates this is hydrostatic pressure reduction during cement slurry setting in the annulus.

Present models and theory can only explain the trend in lab and are not satisfactory for field results. A new model is presented by following the physical process of the pressure reduction. The new model shows that pressure reduction depends on not only gel strength but also the compressibility of cement slurry. Total volume reduction is another major factor in this model besides slurry gel strength used by traditional methods. The total volume reduction includes not only chemical shrinkage and filtration into formation but also the compensated volume from wellbore wall shrinkage and casing string expansion due to the pressure reduction in the annulus.

—D Zhou and A K Wojtanowicz, Louisiana State University

IADC/SPE 59134

Using Particle-Size Distribution Technology for Designing High-Density/High-Performance Cement Slurries in Demanding Frontier Exploration Wells in South Oman

A promising oil source in South Oman is providing challenges to successful cementing operations. The formation is approximately 4,200 m deep with bottom hole pressure of 13,000 psi. There is a very narrow margin between the formation pore and fracture pressure. Also salt saturated mud with weights up to 19.0 lbm/gal is routinely required to drill these wells.

IADC/SPE 59139: This paper discusses a thermally compensated inflatable packer system. The authors say the system reduces the chance of sealing-element failure when inflatable packers or plugs are used in stimulation or when the temperature of the borehole fluid changes more than 10° F.

There has always been a conflict with conventional oilfield cements between optimizing slurry properties for mixing and placement and resulting mechanical properties of set cement necessary for long-term zonal isolation.

The challenge has been successfully dealt with in cementing high-pressure wells in South Oman using a technology adapted from the concrete industry. High-density/high-performance slurry (HDHPS) technology optimizes both slurry and set cement properties simultaneously. Particle Size Distribution (PSD) of various components in the blend is varied to optimize slurry and set cement properties simultaneously. Extensive lab testing and yard trial prior to field application demonstrated the superior performance of HDHPS over conventional cements in both the liquid phase and when set.

—B Jain, Dowell, *et al*

IADC/SPE 59135

Removing Subjective Judgment from Surface Wettability Analysis Aids Displacement

This case-history paper demonstrates that with simple instrumentation operators can accurately determine the apparent wettability state of spacers and preflushes used in cementing operations. Detailed knowledge of the wettability state can enable optimization of surfactants used to displace non-aqueous drilling fluids and leave the casing "'water-wet". Water-wet casing helps minimize the potential for costly remedial zonal isolation treatments.

A laboratory device now being manufactured is the key to accurate wettability assessment. Operation of the device relies an the principle that oil-external drilling fluids do not conduct electricity; water-based spacers do conduct electricity. The apparatus measures implications of wettability by measuring the electrical activity in the test fluid and on the electrode surfaces during the water-wetting process.

—J Heathman, Halliburton Energy Services, *et al*

IADC/SPE 59136

Foam Cementing as a Deterrent to Compaction Damage in Deepwater Production

This case-history paper will present the results of a foam cementing process used during construction on 4 primary casing strings on Shell's Europa project. The process was initiated to help prevent compaction damage associated with deepwater production.

The main focus of the paper will be on the planning, preparation, and execution of the primary cementing on the critical production liner. Because of the presence of highly unconsolidated formations above the producing zone, the reservoir will experience compaction due to depletion. The critical issues for the production liner am effective placement without lost returns (experienced on the discovery well) and mechanical properties needed to help deal with the forces imposed on the wellbore and cement sheath. Minimizing the effects of these forces due to transverse loading help to avoid buckling of the casing. The unique properties of foam cement make it best suited for this application.

—R Faul, Halliburton Energy Services, *et al*

IADC/SPE 59138 (ALTERNATE)

Casing Centralization in Horizontal and High Inclined Wellbores

Casing centralizers are one of the simplest yet most beneficial mechanical aids used in primary cementing. They are designed to position the casing more centrally in the hole, thus reducing running forces and improving displacement efficiency while cementing.

To be effective, the placement of centralizers with respect to spacing and location must be optimized through consideration and evaluation of all parameters and all forces involved. In API Spec 10D, a theoretical model is presented to evaluate the casing deflection, based on lateral and axial loading. While the deflection model itself is considered acceptable, the present study demonstrates that a more realistic determination of axial load is achieved by applying a new method when considering fluid forces. In the API model the effect of the fluid action is limited to the buoyancy forces on the casing. The model presented evaluates the fluid effect in a global way, integrating both the buoyancy effect and horizontal force component acting on the casing. Some examples are shown, developed with a computer program which incorporates the new axial loading model. The results obtained using the new model vary significantly from API 10D, especially in highly inclined and horizontal wellbores. This is due to the different predictions of axial load distribution, producing different standoff values and consequently changing the centralizer requirement. Contrary to the API model and many other centralization models, the study shows the low part of the pipe to be under compression, and this is what generates the most influential difference in centralizer requirements.

—A J Blanco, PDVSA-Intevp SA
—V I Ciccola and E J Limonagi, U Central de Venezuela

IADC/SPE 59139 (ALTERNATE)

Zonal Isolation in Stimulation Treatments and Gas/Water Shutoff Using Thermally Compensated Inflatable Packers and Plugs

This paper provides laboratory- and field-test results of a thermally compensated inflatable packer system. This system greatly reduces the chance of sealing-element failure when inflatable packers or plugs are used in stimulation treatments or any application where the borehole fluid changes temperature more than 10º F. To date, a primary cause of failure in achieving zonal isolation while using inflatable packers and plugs is the change in temperature of the borehole fluid once the packer is set.

Thermally compensated inflatable packers are an innovation in inflatable packer technology. These packers act in a manner unlike conventional inflatables, which are susceptible to temperature differentials as little as 10º F between borehole and internal fluids. These temperature differentials can cause the fluids inside conventional inflatable packers either to expand and rupture the element or to contract and cause the element to lose its seal on the casing wall. Qualification tests and resulting data will be presented, as well as data acquired after a thermally compensated inflatable plug system was deployed in a water injection well.

—Corey E Hoffman and P Wilson, Weatherford Completion and Oilfield Services