e-Drilling;

Advanced Real Time Drilling Modelling, Optimization, Diagnosis and Visualization

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A new generation real time simulation and visualization system designed to integrate all participants involved will enable enhanced collaboration of all drilling and well activities in a global environment.

The system is designed on an open 3-D visualization monitor that can visualize all drilling and well related operations involved.

The system is based on an open system architecture where equipment suppliers, service companies, contractors and operators can be connected via a standard.

Results related to drilling:

- Costly failures will be reduced and better knowledge of the process will be obtained:
  - The driller/directional driller will see if the bit follows the planned well path.
  - Geologists.drilling engineers will be able to see the bit going through different geology layers in real-time.
  - Petro-physicists can see the bit entering seismic information real-time.
  - Accurate depth by visualizing the tally/BHA in real-time.
  - Visualization the bit or tool joint going through restricted areas like the BOP or Casing shoe.
  - Link real-time software models with real-time data to analyse and optimize drilling performance "eg". Visualize well pressure profile and prediction of pressure when drilling ahead.
  - Backtracking of operations in 3D (similar to rewind & forward on a tape recorder).

Models for real-time drilling analyses

e-Drilling will provide the technology elements to realize real time modelling, supervision, optimization, diagnostics, visualization, and control of the drilling process from a remote drilling expert center. These technology elements are:

- An advanced and fast integrated drilling simulator which is capa-
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- Data Quality Module DQM
- Real time supervision methodology for the drilling process using time based drilling data as well as drilling models / the integrated drilling simulator
- Methodology for diagnosis of the drilling state and conditions
- Advisory technology for more optimal drilling
- A Virtual Wellbore, with advanced visualization of the downhole process
- Data flow and computer infrastructure

**Data Quality Module**

Correct processing and interpretation of the data that are acquired in the drilling process is essential for safe as well as reliable interpretation. Today, measured data are often disturbed by physical effects that can lead to faulty interpretation. By systematic modeling of physical effects that influence the measured values, improved drilling data will be obtained for important drilling parameters. In addition to the error correction, algorithms will also be developed for identification of the proper state of the drilling process (drilling, tripping, circulation, making connection or reaming).

Advanced filtering techniques are required to extract as much information as possible from drilling data. This module will therefore address:

- Calculation of important physical parameters from available raw data, e.g. calculation of hook load and surface torque,

**Fig. 1: Typical e-Drilling infrastructure.**
• Determination of drilling status, e.g. whether bit is on or off bottom and whether drillstring is in slips,

• Detection and handling of sensor failure,

• Correction of systematic errors and noise,

• Removal of erroneous or misleading data that are not handled otherwise.

**Real-time models**

The models that form the background of the real-time models are the result of accumulated knowledge from 20 years of continuous R&D and modeling. This knowledge is assembled in an Integrated Drilling Simulator. Models with the appropriate degree of complexity have been selected, and the models have been improved where necessary, and re-implemented using methods that are optimized with respect to challenges in real time applications.

The model basis for the transient and steady state applications has been built with focus on:

• Accurate representation of the physical system

• Flexibility

• Requirements related to real time applications

• High degree of robustness, also when driven by real time data like pump rate, rate of penetration, drillstring rotation rate, torque, and inlet temperature

• Sufficient calculation speed under relevant conditions.

**Fig. 2: Sketch of how different sub-models interact in the Integrated Drilling Simulator.**

The following building blocks are established: Flow/hydraulics, torque/drag, vibrations, Rate of Penetration (ROP), wellbore stability and pore pressure. Some of these models will interact with the mechanical earth model (MEM) as well as with each other.

Some of the elements of the integrated drilling simulator are described in detail below.

**Downhole pressure and flow**

An advanced transient flow and temperature model has been built. The model can handle calculation of

• Pressure/ECD, temperature, and pit volume vs. time while drilling and circulating, including flow of cuttings. Detailed modeling of formation of cuttings bed is beyond current scope, but the model will warn when significant bed formation is expected.

• Detailed modeling of formation of cutting beds is beyond the scope of the technology currently, transient well pressure and flow vs. time during surge and swab.

• ESD and temperature vs. time during static periods, e.g. flow tests.

• Transient pressure and flow vs. time while resuming circulation after static periods.

The model will be calibrated to incorporate effects of slowly drifting model parameters, but still give warnings when relatively rapid significant changes relative to model prediction are observed. The model has been used in design, procedure development and also for real time optimization and follow-up of critical operations.

**Torque/drag**

An advanced torque/drag model has been built. The model will be applied for the calculation types:
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- Calculate WOB with input of hook load or vice versa. Automatic calibration when rotating off bottom can be used.

- Calculate bit torque with input of surface torque or vice versa.

- Back-calculation of friction factor with input of measured surface and bottom hole weights or torques. Friction factor can be monitored with warnings issued on unexpected changes.

- Bit depth correction due to string elasticity. More accurate bit depth will increase value of LWD.

- Initial calibration of rig specific parameters, such as model parameters for force/torque transfer from top drive system to string.

**Benefits are realized through**

- Comparing measured hook load with calculations while tripping, and warn if unexpected deviations occur. Compare with earlier trips to identify expected effects like dog-legs.

- Comparing measured and calculated hook load and torque during connection tests, which typically involves pick up, rotating off bottom, and slack off. Trends in data and calculations are used to obtain early indications on poor hole cleaning.

- Comparing measured torque and ROP while drilling with calculated results to get early indications on poor hole cleaning. Both the torque/drag model and the bit/ROP model will be involved.

**Drilling vibrations**

Algorithms are implemented to help detect drillstring vibrational problems. When such problems are detected, solutions will be recommended. Recommendations might include active damping, such as the algorithm developed to cure stick-slip motion of the drillstring, or passive adjustments to the drilling parameters weight on bit or rotary speed. The algorithms can also be used in planning a wellpath and BHA design to help avoid drilling vibrations.

**ROP**

While drilling a well, the rate of penetration will vary. Some of this variation is due to variations in the formation parameters and some is due to variation in the drilling parameters. The important formation parameters are the compressive strength and the

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**Fig.3: Screen shots from the virtual wellbore 3D visualization tool.**

Drillers view with focus on bit movement in the well.

Visualization of wash-out, tight spots and cutting bed.

Realtime modeling (installation).

Casing shoe.

Realtime view of ECD model data with PWD data from MWD tool.

Geological layers.
formation pressure. Drilling parameters include a description of the bit, the weight on bit, the rotary speed, the borehole pressure, the mud flow rate and viscosity. Analysis of these variations, intentional or incidental, can give more information on conditions downhole than is generally assumed possible. Time-based logging data is a prerequisite for this analysis.

The analysis of the ROP will be performed simultaneously with analysis of (1) torque on bit/weight on bit relationship, (2) torque and drag analysis, (3) monitoring of hole cleaning, and (4) well pressure, but the main focus will be on ROP.

**Wellbore stability**

Considerable expertise exist in well bore stability. Existing models are expanded to estimate the probability of well bore instability based on formation description and the temperature and pressure history along the well path.

**Pore Pressure**

The multi-purpose geo-pressure modeling tool PRESSIM includes all processes relevant to pressure generation and dissipation.

**Process & operation module**

The integrated drilling simulator will be driven by the drilling data, and computed results will be compared with measured values to generate an initial diagnosis. Trend curves of measured drilling parameters versus calculated will be used to visualize the drilling history. The process and operational related modules will use results from the basic process models to discover upcoming problems as early as possible, and to further analyze the drilling data when problems are suspected. These will run in the background and give input to the active process and operational related modules during the various drilling phases.

**Diagnosis**

Various specific process and operational related modules will be built on top of the basic process models for interpretation and diagnosis purposes.

**Forward Looking**

Automatic forward-looking is performed by the calibrated models by projecting the drilling process a given time period ahead.

**Results**

This system will enable decision makers to have better insight into the status of the well and formation surrounding the well and thus make better and quicker decisions. This is of particular importance when problems or unusual situations arise and experts are called in to make decisions. They will quickly be able to grasp the situation and make the correct decision.

**Conclusion**

By combining, in real-time; simulation and drilling analysis, interfacing; and 3D visualization you will get a system that all involved personnel can use as their common working tool.

This tool will easily reflect what is going on now and also give the user access to historical data (playback scenarios) for experience exchange and training.

The overall result is a more cost effective and safer drilling and well construction operation.