Reservoir Monitoring Consortium (RMC)

WELLBORE MONITORING FOR KICK DETECTION

Ante, M. A., Rose, K. K., Tost, B.

Los Angeles, CA
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Patent Application: S-135475
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Causes of Kick

A kick requires only **one** condition:

\[ P_{\text{mud}} < P_{\text{formation}} \]

**Possible Causes include:**

- Unbalanced fluid level during tripping
- Low density drilling fluid
- Over-pressure formation
- Gas/oil/water cut
- Etc.

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Early Detection is Critical

- Minimize size of influx
- Lower volume/flow rate for surface equipment
<table>
<thead>
<tr>
<th>Available Techniques to Detect Kick</th>
</tr>
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<tbody>
<tr>
<td><strong>Mud logging (monitor pit gain)</strong></td>
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<tr>
<td>Measures increase in the ‘close loop’ of mud circulation system.</td>
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<tr>
<td>Depends on factors such as wellbore hydraulics and mud lag time to reach the surface.</td>
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<td>Critical time for decision making is lost.</td>
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<td><strong>Pore pressure estimation from MWD/LWD measurements (resistivity, sonic and density logs).</strong></td>
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<tr>
<td>Helps to define safe mud weight window in real time and for maintaining wellbore stability as drilling progresses.</td>
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<tr>
<td><strong>Acoustic methods for gas kick detection</strong></td>
</tr>
<tr>
<td>Pressure waves travel faster in gas-cut mud</td>
</tr>
<tr>
<td>Monitor T-T</td>
</tr>
<tr>
<td><strong>State-of-the-art kick simulators</strong></td>
</tr>
</tbody>
</table>
MWD and LWD

• Traditionally, MWD and LWD have been leveraged to enable while-drilling validation of pre-drill design and also allow midcourse corrections in well design.

• More recently, emerging Pressure-While-Drilling and Logging-While-Drilling, Seismic-While-Drilling allows proactive decisions on mud weight programs to improve safety and efficiency.

• Instantaneous process allows key decisions to be made while drilling.

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MWD and LWD

MWD
- Acquires wellbore deviation directional surveys (geometry, toolface orientation during drilling process)
- Collects drilling mechanics data (downhole torque, pressure, vibration etc)

LWD
- Acquires petrophysical data (resistivity, porosity, natural gamma ray etc).
- Tool located in drill collars immediately above drill bit
- Information recorded in downhole computer memory and is transmitted only after tool is retrieved at the surface.

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Integrating MWD and LWD for Real Time Kick Detection

- Original applications in direction and inclination of well to optimize well placement

**Drilling mechanics**
- Torque
- WOB
- Vibration
- DH temperature
- etc.

**Formation properties**
- density
- porosity
- pressure
- Resistivity
- Sonic
- Gamma radiation

**Borehole Properties**
- Temperature
- Pressure

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Optimizing MWD and LWD for Kick Detection

Conventional Approach

Approach

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What MWD/LWD Techniques Can Detect HC

- Near borehole information is usually filtered out as noise in a bid to determine formation properties.
- By identifying MWD/LWD measurements that change with fluid type and composition, we can develop a method to evaluate check wellbore influx.

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Data Transmission Methods

- **Mud Pulse Telemetry**
  - bandwidths under 10bps
  - data rate drops with increased depth to as low as 1.5-3bps at 35,000-40,000ft
  - data compression is used to increase effective data rate

- **Electromagnetic Telemetry**
  - data rates up to 10bps
  - degree of signal attenuation increases with depth affecting transmission

- **Wired Drill Pipe**
  - better data transmission rate than mud pulse or EMT
  - upwards of 1Mbps

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Challenge for Data Delivery

Need to not only measure but transmit critical information from downhole to surface continuously and in real time.

Downhole data may be available but data rates are sparse and wellbore measurements compete with transmission of other subsurface data.

Telemetry rates with continuous wave pulsing can reach up to 24 bps, but more commonly 6 bps.

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Selective Data Transmission

• Typically, measurements like GR or density may require about 8 bits and annular pressure about 16 bits.
• With only 6 bps transmission rate, there is a need to selectively transmit critical data in real time.
• That is, data necessary for monitoring and improving drilling process.
• Tool internal memory records almost all downhole data at high data rates and so non-critical data can be evaluated when tool is retrieved.

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Selective Data Transmission

Downhole Data

Critical: Transmit in Real Time

- Kick Monitoring Data

Non-Critical: Store in Tool Memory

- Drilling Mechanics Monitoring
- Non-essentials for monitoring

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Evaluation Methods

Many potential methods can be tested, including:

• Weighted/Moving Averages
• Defined Limiting Thresholds
• Short Term Average / Long Term Average
• Wavelet Transform
• Template Matching
• Neural Network
Wellbore Kick Detection: Methodology

**Recognition**
- Detecting changes in dynamic properties of signal.
- Segmentation of signals through Discrete Wavelet Transforms (DWT) – **Generalized form of Fourier Transform**.
- Establish links between segmented signals and physical properties.
- Neural network ...

**Real Time Monitoring**
- Use of statistical parameters to model changing behavior using moving average methods.
- Updating gains with adaptive algorithms to track quick variation of the parameters.
- Model based monitoring
- Mud composition

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Methodology

- Picking/identifying drilling mud arrival from MWD/LWD signals
- Eliminate the effect of drilling noise from signal
- Analyze waveforms to identify trends for influx at different conditions
- Integrating results in real-time measurement

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Signal Recognition Using DWT

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Start Drilling

Make Wellbore Geophysical Measurement

Total Geophysical Measurement

Unspecified Data Filtering, Extract Annular Data from Total Measurement

Annular Data

Compress Data and Transmit to Surface via Telemetry

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NO

Concatenate New Annular Data onto Moving Average References

YES

Are Annular Data within Moving Average Boundaries?

PASS: Permit Annular Data to be Bundled

FAIL: Send Warning Signal, Take Appropriate Action to Contain Kick (e.g. Increase Drilling Fluid Circulation Rate, Increase Drilling Fluid Density, Close Well)

Concateenate New Annular Data onto Moving Average References

Continue Drilling

Develop New Moving Average Curves Including Most Recent Data Point

Moving Average References

Compare Annular Data to Moving Average References

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Flow Chart

Conventional processing:
- Raw log data from tool
  - Resistivity
  - Density
  - Sonic
    - Signal recognition from wavelet analysis
    - Expected borehole profile per log

Kick processing:
- Downhole processing for borehole values
  - Values/Signal in acceptable range of borehole profile?
    - Yes: Continue drilling
    - No: At least two?
      - Yes: Possible Risk
      - No: Continue drilling

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Data

Courtesy: Turkish Petroleum Corporation, TPAO

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Sensitivity Analysis

The methods will be evaluated base upon criteria such as:

• When using real data
• Number of events detected
• Number of events not detected
• Severity of events reported vs. actual
• Effect of introduced noise
Advantages

• Can utilize measurements from LWD, MWD and SWD tools
• Improved kick diagnostic
• Rapid integration of data ahead of kick for faster decision making
• Minimal false alarm through combination of different measurements and methods
• Distinguish kick from formation-related spike
• Kick-fluid identification

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Conclusion

- Importance of real-time kick detection
- Need to fully optimize signals from MWD/LWD
- Establishing links between signal character versus borehole and formation properties, as well as drilling parameters.

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• Excerpts from ‘Schlumberger Well Control Training PL’. http://dc349.4shared.com/doc/ HMB1wsL/preview.html
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• Meguerdijian, M., USC Directed Research project work
• Walker, R., USC Directed Research project work

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THANK YOU

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