Data-Driven PHM Applications for Oil & Gas Industry

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Agenda

- Background
- Our Vision & Mission, Team, Process
- Applications
  - Failure Detection for Drilling Tool
  - Condition Monitoring for Blow-Out Preventers
  - Overviews: Frac Pumps, beyond Equipment
- Closing Remarks
Background – Oilfield Technologies

Reservoir Characterization

Drilling

Production
Background – Falling costs of sensors, computing, storage

Analytics is radically changing all economic activities – at a fast pace

- Business Analytics
- Equipment Analytics
- Social Media Analytics

*DSource: Banyanhills.com*
Data Driven Equipment Monitoring – The Big Picture

VISION
Data driven decision making with zero unplanned down time

MISSION
AVOID or MITIGATE Non Productive Time
REDUCE Total Cost of Ownership
IMPROVE Efficiency
Data Driven Equipment Monitoring – The Big Picture

- Fault detection/Diagnostics/Prognostics Platform
- Engineering
- Identify design improvement
- Communicate PHM channels
- Enhanced product
- Equipment
- Decision Support
- Repairs
- Maintenance
- Parts
- Inventory
- Manufacturing
- Supply
- CBM actions
- Health index
- Parts
- Phillips
- Enhance product
- Health index
The Analytics Team

Global footprint

Multidisciplinary

- Agile, Highly Competent Data Science & Digital Product Development Team
- Top schools
- Global Tech Centers
- Product Deployment Across Segments

Working on high-impact problems across many Schlumberger Product Lines
Phases in our projects

1. Data Ingestion
   - Sensor Data (temperature, vibration, current, pressure, RPM)
   - Controls Data (open/close, status, modes)
   - Maintenance Data
   - Formats: CSV, Binary, Historian, SQL

2. Exploration & Transformation
   - Visualize: Histogram, Scatter, Heat Map
   - Compute: Features, Correlation, Filter, Search, Sort, Statistics

3. Algorithm Development
   - Data Preprocess
   - Anomaly Detection
   - Regression
   - Classification
   - Automation

4. Deployment
   - Real-time Monitoring or
   - On-demand Analysis (periodic check, pre-job check, diagnostic)
   - Web Application
   - SLB Software + Cloud API
Application 1: Logging-while-drilling (LWD) tool

**Problem description & relevance**

- Multifunction Logging-While-Drilling (LWD) tool
- Focus subsystem: Pulsed Neutron Generator **PNG** - self-contained particle accelerator
- Typical cycle: 100 hours at temp 150C, pressures of 20,000psi, significant shock & vibration

- Acquire 1,000 tool channels during runs
- After each job, technicians in Maintenance Base use tool data to decide on maintenance needed before tool is sent for next job
- PNG functionality is critical to core tool measurements
Application 1: Logging-while-drilling (LWD) tool

Previous solution – manual data analysis by experts
- Data analysis done manually: very time consuming, prone to error
- Large number of potential failure modes, many intermittent or only evident under the stress of down-hole conditions
- Experts added personal biases – need objective approach

New solution approach
Construct Health Indicator (HI) from PNG sensor data
1. Stat summary of selected channels
2. First principal component (PC1) from features
3. Empirical Mode Decomposition: from PC1 to intrinsic mode functions + residual signal
4. Residual signal shows rate of change in variance with time = developing PNG degradation
5. Decision-tree, trained on HIs of different runs labeled as healthy or faulty by expert
Application 1: Logging-while-drilling (LWD) tool

New solution approach

Table 1. Confusion matrix for model testing

<table>
<thead>
<tr>
<th>Correct label</th>
<th>Healthy</th>
<th>Faulty</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy</td>
<td>34</td>
<td>1</td>
<td>35</td>
</tr>
<tr>
<td>Faulty</td>
<td>0</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Total</td>
<td>34</td>
<td>26</td>
<td>60</td>
</tr>
</tbody>
</table>
Application 2: Automated condition monitoring for BoPs

Blow-out Preventers

BoP is safety-critical drilling rig component; final layer of protection from a hazardous blowout

Application 2: Automated condition monitoring for BoPs

Problem description & relevance

Wellbore Packers isolate pressure from well in event of a ‘kick’. Packers during operation (above) and during test or ‘kick’ (below)

- 45 out of 59 rigs operating in Gulf of Mexico reported component failures of well control related equipment in 2017 (BSEE)

- The integrity of packers (leaks due to aging) must be assessed regularly by simulating pressures on them

- Needs:
  1) Test planning – to ensure time efficient testing of all critical components
  2) Once test data available, generate accurate Health Index for each component

Example of Planned Test Configuration

BOP Stack with 19x components: 1x Annular, 2x Shear Ram, 3x Pipe Ram, 11x Gate valves and 2x Line isolation valves
Application 2: Automated condition monitoring for BOPs

Automated Pressure Point identification from test data

Health index evaluation

Health indices definition

\[ HI(s) = \frac{\max(T_s - s, 0)}{\max|T_s|} \]

\[ HI(d) = \frac{\max(T_d - d, 0)}{d} \]

\[ HI = HI(s) + HI(d) \]
Application 2: Automated condition monitoring for BOPs

Condition Monitoring Process Flow for BOP Wellbore Packer

1. Data Source Selection and Data Processing
2. Identification of Test Events
3. Feature Extraction
4. Health Index Evaluation
5. Classification of Test Configuration
6. Benchmarking and Health Decision

Health indices for *Middle Pipe Ram* over Mach 2017 – Feb 2018

- decay/window
- slope
Another application: Frac Pumps

Frac Pumps Monitoring - Impact

1,289 field notifications sent
1,179 incidents avoided
$7.7 million in M&S savings

- Schlumberger Full-Year 2016 Results
- ... The Reliability Support Center in Denton implemented prognostic health management (PHM), using real-time pump data collected from field locations. During the six months after implementation, PHM achieved an estimated $6 million of savings in operation costs ...
Many other applications, beyond Equipment

- Operation Planning
- Staffing Planning
- Engineering & Manufacturing
- Supply Chain Optimization
- Asset & Production Optimization
- Research & Innovation
Closing Remarks

Asset Health Management is a key enabler for:

- Lowering Total Cost of Ownership for O&G Tools and Equipment
- Improve Service Quality
- Reduce NPT
- Enhanced Availability & Productivity
- Situational Awareness and Planning

New Business Models can bring new revenue streams for OEMs via Service Agreements – pay by performance, pay by uptime, lease business models, etc.

Though there are bottlenecks, recent advances in IoT, Cloud and Machine Learning have made it easier to acquire, transmit, analyze and forecast equipment conditions and RUL, enhancing predictive planning & resource management abilities.