Predict stuck pipe events using Exebenus Pulse ML agents
Increase productive time by predicting and preempting stuck pipe conditions

Exebenus Pulse machine learning (ML) agents use data that is readily available in all well operations to provide real-time, dynamic predictions and trends, enabling operators to avoid undesired events.

**PREVENTING HIGH-RISK CONDITIONS**

**Exebenus Pulse Stuck Pipe ML agents** predict, in real-time, high-risk conditions such as pressure differentials, hole cleaning conditions and wellbore geometry issues that, without intervention, typically result in stuck pipe situations.

When used on historical data as part of offset well analysis, the agents can identify unreported near misses and provide guidance for optimizing performance in the future.

ML agents are designed for engineers to

- Optimize pre/post job offset well and investigative root cause analysis
- Perform real-time predictive, situational awareness and performance analysis throughout operations.

ML agents consume real-time or historical WITSML data and provide WITSML data output. To minimize user training, they integrate with existing real-time WITSML viewers and operations center workflows to monitor, analyze and advise rig crews.

**SUCCESSFUL DEPLOYMENT AND EXPERIENCES**

For new deployments, ML agents are trained using historical data from one or two wells, preferably from the area in which they will be used, or from wells sharing a similar trajectory design. Data showing historical stuck pipe events is beneficial, but not required.

**Exebenus Pulse Stuck Pipe ML agents** are supplied in one package. They work independently to solve different stuck pipe scenarios.
SMART USE OF REAL-TIME DATA

To create easily understandable and trustworthy predictions, the ML agents use parameters that are familiar to engineers. The agents have easy-to-read color coding and text information. As the agents provide predictions, their analysis is presented in the monitoring display as trends, warnings and alarms related to the predicted problem.

The sensitivity level of each agent’s warning and alarm setting is configurable to provide engineers with the best possible situational awareness. An agent’s predictive time depends on the nature of the operation, the sensitivity configuration, and the type of look-ahead, predictive signs that exist. A typical setup gives the engineer three warnings prior to raising the alarm.

In addition to the Stuck Pipe ML agents, the software issues alarms when data is missing or the connection to the rig is lost.

THE POWER OF EXEBENUS PULSE ML AGENTS

Exebenus Pulse ML agents comprise a cloud-based, stand-alone software as a service (SaaS) solution. The agents can be hosted on a public cloud (e.g. Microsoft Azure) or installed on your in-house, private cloud.

Exebenus has partnered with IBM and has embedded the IBM Watson technology in the ML agents.

The design of the Exebenus ML agents is based on our deep understanding of drilling and completions operations and the associated data. Exebenus machine learning experts continue to work closely with domain experts to ensure that the agents are robust and highly predictive.

Prior to deploying Exebenus Pulse ML agents, our experts will work with your organization to recommend the optimal configuration and setup for managing any number of well operations, including connectivity, IT infrastructure and hardware.
<table>
<thead>
<tr>
<th>STUCK PIPE ML AGENTS</th>
<th>WARNING/ALARMS</th>
<th>PREDICTIVE TIME</th>
<th>INPUT DATA</th>
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</thead>
<tbody>
<tr>
<td>Differential sticking (DS)</td>
<td>The warning is triggered by a decreasing or increasing drag trend in combination with extended (more than 10 minutes) stand-still or connection time.</td>
<td>½ hour – 4 hours ahead</td>
<td>Time, bit depth, hole depth, hookload, flow rate, RPM, block position</td>
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<tr>
<td>Wellbore geometry (WG)</td>
<td>The warning is triggered when there is a predicted increased in drag at depths where high dog-leg severity is planned and/or drilled. Warnings from previous runs in the same section are remembered.</td>
<td>½ hour to one run ahead</td>
<td>Time, bit depth, hole depth, hookload, flow rate, RPM, trajectory, block position</td>
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<tr>
<td>Hole cleaning (HC)</td>
<td>The warning is triggered when there is an increased predicted ECD trend in combination with a diverging pressure vs flow relationship.</td>
<td>½ hour – 4 hours ahead</td>
<td>Time, bit depth, hole depth, hookload, flow rate, RPM, trajectory, mud density in, ROP, stand-pipe pressure</td>
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</table>

Example shows a tripping-in scenario. The red prediction ahead of time is dropping because we have a buoyancy effect in the mud. A low to medium differential sticking warning is issued as every joint goes in the hole. Data courtesy of PETRONAS.

Example shows a yellow warning is issued as predicted ECD is increasing (black) and the relationship between flow and standpipe pressure. Once the flow rate has been changed the ECD prediction (magenta) decreases and situation goes back to normal. Data courtesy of PETRONAS.
EXEBENUS PULSE

The Exebenus Pulse solutions digitalizes the information exchange between planning and operations. Bridging the digital footprint of past and current operations, the solution automatically generates validated, digital operating procedures for drilling and completions operations. Exebenus Pulse facilitates dynamic interaction between planner and crew, validates actions, flags deviations in real time and captures best practices for future implementation. The Exebenus Pulse ML agents pre-empt well conditions and increase situation awareness and operational productivity.