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Horizontal Well Downhole Dynamometer Data Acquisition

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Project sponsored by ALRDC
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(((ECHOMETER)))
Project Goal & Overview

- Gather true measured data on both deviated & horizontal rod-pumped wells
- Actual downhole load & position: dynagraph cards
- Provide that measured downhole data to industry
- Improve our understanding of side loads, bending, friction, damping, and other factors resulting from well deviation
Rod Pump Diagnostics: Introduction

- Historically, the pump condition has been determined by dynamometer analysis.
- A surface dynamometer measures position and load to generate a surface card.
- The downhole card is calculated by solving the 1D wave equation (the surface card is projected downhole).
- The solution removes all dynamics in the surface card to show you the resulting work at the pump.
- Since the rod string acts as a transmission line for the pump, any distortion in load signals result in poor downhole resolution.

Downhole Dynamometer
Rod Pump Diagnostics: Current Pitfalls

- The diagnostic solution to the 1D wave equation assumes all elastic deformation originates at the pump
  a) Shallow friction distorts both Gross Stroke and Fluid Load
  b) Deep deviation will tend to mostly affect Fluid Load

- The damping term of the wave equation is only meant to account for viscous forces, not mechanical friction

- Furthermore “...incorrect dynamometer data can give false indication of buckling anywhere in the string” - Gibbs
Example 1: Vertical Wellbore

- Reliable calculations:
  - Pump Intake Pressure
  - Pump Efficiency
  - Pump Displacement
  - Rod Loading

- Additional observations:
  - Well is pumped off
  - Tubing movement is apparent
  - Confidence in original design: Pumping conditions can be duplicated by predictive software
Example 2: Deep Deviation

- **Reliable calculations:**
  - Possibly Pump Intake Pressure
  - Possibly Pump Efficiency
  - Possibly Pump Displacement
  - Possibly Rod Loading

- **Additional observations:**
  - Well is close to pumped off
  - Confidence in original design: Pumping conditions can be (relatively) duplicated by predictive software
Example 3: Shallow Deviation

- **Reliable calculations:**
  - No reliable downhole calculation available
  - Both the Net Stroke and Fluid Load are distorted

- **Additional observations:**
  - Production is the only proxy for the condition of the pump
  - Incomplete fillage calculations will not be reliable

Wellbore Profile and Corresponding Dynamometer
Project Overview: What is the HWDDDA

- The Artificial Lift Research and Development Council (ALRDC) is spearheading an effort to better understand pumping deviated wells.
- The Horizontal Well Downhole Dynamometer Data Acquisition Project (HWDDDA) has assembled operators and service companies together to solve this issue.
- Project planning and tool design are both underway, but funding is needed for both tool manufacturing and testing.

Industry Support

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<tr>
<td>Accutant Solutions LLC</td>
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<td>ALRDC</td>
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<td>Albert Engineering</td>
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<td>Black Gold Pump</td>
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<td>BOPCO</td>
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<td>Echometer</td>
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<td>Forty A&amp;M LLC</td>
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<td>John Crane</td>
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<td>Marathon Oil</td>
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<td>Occidental Petroleum</td>
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<td>Petrolog</td>
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<td>RTP Company</td>
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<td>Shell</td>
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<td>Tenaris</td>
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<td>UT Austin</td>
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<td>Weatherford International</td>
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<td>Wells Whisper</td>
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The ALRDC is an International, Private, Not for Profit organization. There are currently about 2,900 members. Among its functions are:

• Sponsoring International Workshops and Conferences on Sucker Rod Pumping, Gas Well Deliquification, and Gas-Lift

• Helping with other Workshops and Conferences on Electrical Submersible Pumping and Progressing Cavity Pumping

• Helping to sponsor important Artificial Lift R&D projects such as this Horizontal Well Downhole Dynamometer Data Acquisition project

• Maintaining a Technical Library of Artificial Lift reports, articles, etc.

• Providing Scholarships for Students of Artificial Lift at several major Universities
HWDDDA Project Structure

- **General Committee:**
  - Manage overall project
  - Report progress to ALRDC R&D Committee

- **Business Sub-Committee:**
  - Define/manage budget and document project

- **Tool Design/Manufacturing/Testing Sub-Committee:**
  - Define tool specifications and tool testing requirements
  - Select tool manufacturer

- **Tool Deployment/Retrieval/Data Gathering Sub-Committee:**
  - Outline testing procedures and well selection criteria
  - Gather data

- **Data Validation/Maintenance Sub-Committee:**
  - Validate data, build and maintain database
Historical Perspective - Sandia

- Gathered and published data from multiple test wells
- Project took place during a period of low oil prices
- Proved wave equation methods are sound and accurate

But… This only holds for vertical wells

Number of well drilled since 1995 (Sandia)?
  - How many of those wells are vertical holes?
Project Overview: Tools

- Directly measured load and position data is required to validate or to improve the accuracy of the existing software for deviated wells.
- A new generation of down-hole sensors are required to gather true measured forces and stresses.
- This data will be used to improve design software for rod systems.
- Participants in the project will have first access to data, results, and developed tools.
Project Overview: Benefits of Involvement

- This tool will help the industry better design predictive and diagnostic software for deviated wells
- However, direct observation of rod string dynamics will also help verify other understood dynamics, but in deviated wells. This includes:
  - Deviation effects on rod loading
  - Tubing movement in deep deviated wells
  - Potential sources of compressive loading in a rod string
  - Effects of fluid pound/gas interference on rod stress
  - Effects of pumping speed on plunger velocity/net stroke
  - Effects of interstroke speed changes on rod loading
  - Effects of stroke length on rod loading
  - Benefits of specialty pumps on system performance (VSP, PA plungers, etc.)
  - Calculating pump intake pressures with deviation
  - Appropriate surface data collection devices (inclinometer, Halls, etc.)
Project Overview: Test Scenarios

• Pump Considerations:
  – Fluid Pound
  – Gas Compression

• Operational Considerations:
  – Vary SPM
  – Vary Stoke Length
  – Vary Inter-stroke Speed (proxy for pumping unit geometry testing)
  – Valve Checks (PIP calculations)

• Design Considerations:
  – Point of Initial Deviation
  – Sinker Bar Length/OD
  – Taper % (87, 86, etc.)
  – Specialty Pumps
  – Guiding
Industry Support

• Developing & manufacturing downhole electronics is an essential part of this project
  – Need industry financing and/or volunteer expertise

• Need deviated & horizontal test wells
  – Wells & workover resources to be provided by Operating Companies
  – Data will be stored on the tools, which will require pulling the well
  – Detailed well files need to be provided and will be made public (well names can be redacted)

• Project & data management resources
Conclusions

• Improved downhole models can result in significant operational expense reductions
  – Better decisions and well designs
  – We can’t eliminate downhole friction, but we should be able to design around it, once better understood
• Gathering real-world data is a first & significant step

“to measure is to know – if you cannot measure it, you cannot improve it”
– Lord Kelvin
Next Steps

• Join one or more sub-committee(s) and help direct this project

• You can help:
  – Develop testing procedures
  – Participate in tool & data specifications to be implemented by the operations group
  – Provide resources and funding
  – Identify & allow access to test wells
  – Participate in testing
  – Get early access to data and tools
Appendix and Endorsements
## Dynamometer Tool Specifications

<table>
<thead>
<tr>
<th>Feature</th>
<th>Units</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Axial/Bending Loads</td>
<td>min/in, lbf</td>
<td>3 Strain Gages / Load Cells</td>
</tr>
<tr>
<td>Stroke Position</td>
<td>inches</td>
<td>3 Axis Accelerometers</td>
</tr>
<tr>
<td>Lateral Acceleration</td>
<td>G's</td>
<td></td>
</tr>
<tr>
<td>Fluid Pressure Front</td>
<td>psig</td>
<td>Ported</td>
</tr>
<tr>
<td>Differential Pressure Across Tool</td>
<td>psig</td>
<td>Ported</td>
</tr>
<tr>
<td>Temperature</td>
<td>°F</td>
<td>Internal</td>
</tr>
<tr>
<td>Extra Channels</td>
<td></td>
<td>Possible Dedicated Axial Load Cell</td>
</tr>
<tr>
<td>Data Acquisition Type</td>
<td></td>
<td>synchronous between units @ ambient</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Post processing required to align Timing)</td>
</tr>
<tr>
<td>Length</td>
<td>inches</td>
<td>&lt;30 inches</td>
</tr>
<tr>
<td>Diameter (OD)</td>
<td>inches</td>
<td>1.5 – 1.75</td>
</tr>
<tr>
<td>Temperature Rating</td>
<td>°F</td>
<td>upper Limit Min 185°F, Max 300°F</td>
</tr>
<tr>
<td>Sampling Rate</td>
<td>Hz</td>
<td>60-200</td>
</tr>
<tr>
<td>Available Storage</td>
<td>Bytes</td>
<td>24 hrs. run time @ Max Sample Rate</td>
</tr>
<tr>
<td>Channels</td>
<td></td>
<td>14</td>
</tr>
<tr>
<td>DAQ Resolution</td>
<td>bit</td>
<td>12-16</td>
</tr>
<tr>
<td>Load Capability</td>
<td>lbf</td>
<td>30,000 (Deeper and Horizontal)</td>
</tr>
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“Many of the several thousand of wells that have been completed as deviated or horizontal wells are currently using or in the near future will be using rod pumps to produce economically. Rod string design and pump operation analysis from dynamometer measurements are now undertaken by computer models originally developed for vertical wells and validated by the industry sponsored SANDIA Downhole Dynamometer project. No such validation has been performed on the rod string computer models that have been extended to deviated wellbores, those models are based purely on theoretical assumptions.

It is unwise and economically risky to apply the results of such extended models without having adequate validation of their accuracy.

Directly measured load data is required to perform such validation or to improve the accuracy of the existing software. The principal objective of the proposed project is to provide the necessary data about actual loading experienced by the rod string in a variety of non-vertical wellbore geometries. This task requires the development of a new generation of down-hole sensors and performing field measurements through the collaboration of operators and service companies under the guidance of ALRDC and its members. The success of this project rests in the willingness of all companies that use or provide sucker rod pumping systems to participate in this effort.”
“I wholeheartedly support the Horizontal Well Downhole Dynamometer Data Acquisition Project (HWDDDA). This is a logical and much needed extension of the 1990s work which pertained to vertical wells. My company, Nabla, participated in the earlier project. Our role was to make surface dynamometer measurements at the exact same time as the downhole dynamometer tool was making its measurements. The surface data was used in various downhole card programs for comparison with actual cards being measured with the downhole dynamometer (Albert) tool. In this way the downhole card programs could be evaluated and improved.

Our industry now finds itself in the era of horizontal wells and massive frac jobs. Horizontal wells are deviated before they reach the horizontal. Our industry needs downhole measurements in deviated wells that serve the same purposes that the 1990s measurements served for vertical or near vertical wells.

The work proposed for HWDDDA strikes close to my heart. The current methods for deviated wells trace to my 1992 SPE paper “Design and Diagnosis of Deviated Rod-Pumped Wells”. The downhole friction law in that work was largely theoretical. The practical import of the Gibbs Conjecture is that the precision of pump cards can be improved by improving the friction law in the wave equation. This is exactly what can happen when downhole measurements from the HWDDDA project become available. The theoretical law now used can be evaluated or replaced by a better law.”
“While the Sucker Rod Lift (SRL) method continues to be the most used technique for producing all types of oil, gas, vertical, deviated and horizontal wells, the main computer program software design tool has been recently evaluated showing variations in anticipated downhole loads at various depths in the field tested wells. This evaluation showed that there still are misconceptions and assumptions such as compressive loads and buckling that provide a wide variation compared to the Sandia test data obtained a few years ago.

Over time the computer design programs have been improved and have been modified to try to provide a more accurate prediction of rod string loads. However, downhole deviation surveys and resulting side loads were not originally collected during the Sandia study, which may have contributed to the differences in the expected loads.

Based upon these results a new project has been developed under the coordination of the Artificial Lift Research and Development Consortium (ALRDC) to attempt the development of a current generation downhole data collection tool and well evaluation testing to provide the industry with a more accurate data base to be used to develop better design software programs. This industry study should provide the much needed details on downhole deviation effects in vertical, horizontal, S-type and highly deviated SRL wells. Ultimately, these results should be able to answer the questions on the rod string loads with well depth and whether or not there is compression and/or buckling of the rod string with depth.”
“Sucker rod pumping is the most highly used form of artificial lift in the world. And these days, most new wells are either highly directional or horizontal. The software used by the industry to design sucker rod strings is based on data collected in vertical wells. Therefore, it isn’t sufficiently accurate for design and analysis of rod strings in our newer wells.

ALRDC is excited to help sponsor an industry-wide R&D project to collect downhole dynamometer data on deviated and horizontal wells. This project provides the opportunity for many companies to share in the gathering and use of this new understanding. It can be used to enhance the design and analysis tools we use. This will provide significant technical and economic advantages to all who market, design, install, and use sucker rod pumping in deviated wells.

All companies that provide or use sucker rod pumping are encouraged to join this effort.”

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