ADAPTING PUMPING METHODS TO HIGHLY DEVIATED WELLS

Ivory Sebastian Villegas

Bob L. Herd Department of Petroleum Engineering, Texas Tech University

ABSTRACT

The longevity and efficiency of sucker rod pump (SRP) systems in highly deviated wells depend on strategic design adaptations that mitigate equipment wear and optimize production. High dogleg severity (DLS) and wellbore tortuosity impose significant challenges, leading to increased sideloading, pump inefficiencies, rod fatigue, and tubing wear. This paper explores a tailored SRP strategy incorporating deep pump setting, sideloading distribution, and wear mitigation techniques to enhance system durability and economic life. Tools and methodologies, including rod guides, long stroke pumping units, and gas management solutions are examined to ensure optimal system performance and life. The effectiveness of high-resolution survey data (Gyrodata) is also considered in assessing wellbore conditions.

Keywords: Sucker rod pump, wellbore tortuosity, dogleg severity, sideloading, artificial lift, Gyrodata, highly deviated wells

PROBLEM STATEMENT

Early and high deviations in oil and gas wells present great challenges when implementing artificial lift systems (ALS), particularly pumping methods such as electric submersible pumps (ESPs) and SRPs. While these methods have proven to be effective in reservoir drawdown, modern well geometry often limits their long-term functionality in wellbore sections experiencing high DLS values. These deviations introduce excessive mechanical stresses that can deform ESP components and greatly accelerate rod and tubing wear in SRP systems (Zhao et al., 2019). The increased frequency of failures leads to more frequent workovers, expensive equipment replacements, and substantial downtime. These issues directly affect the economic viability of production operations.

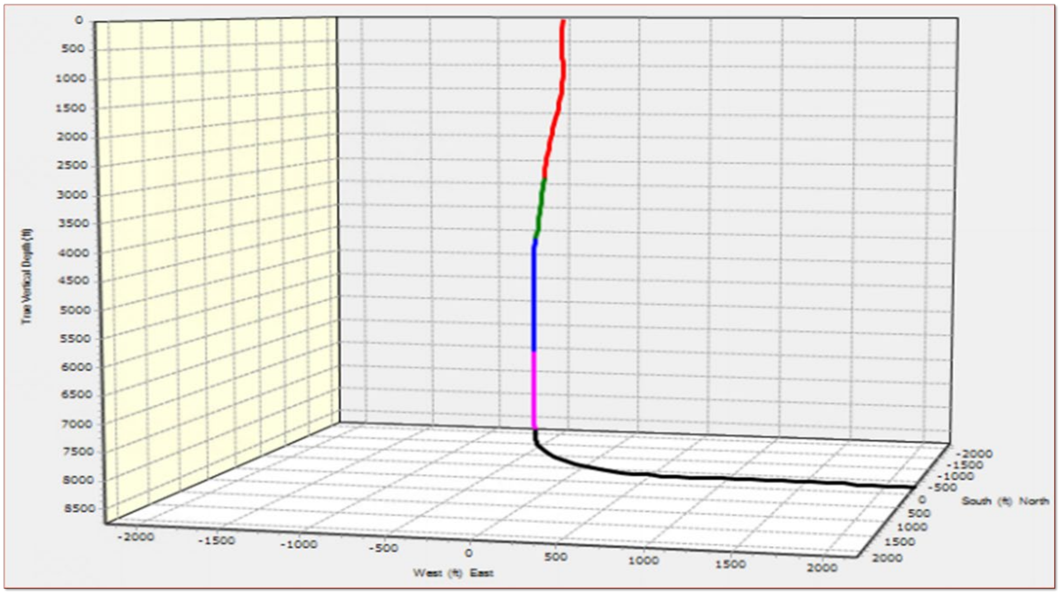

Figure 1 – Deviated well path example (generated in RodStar)

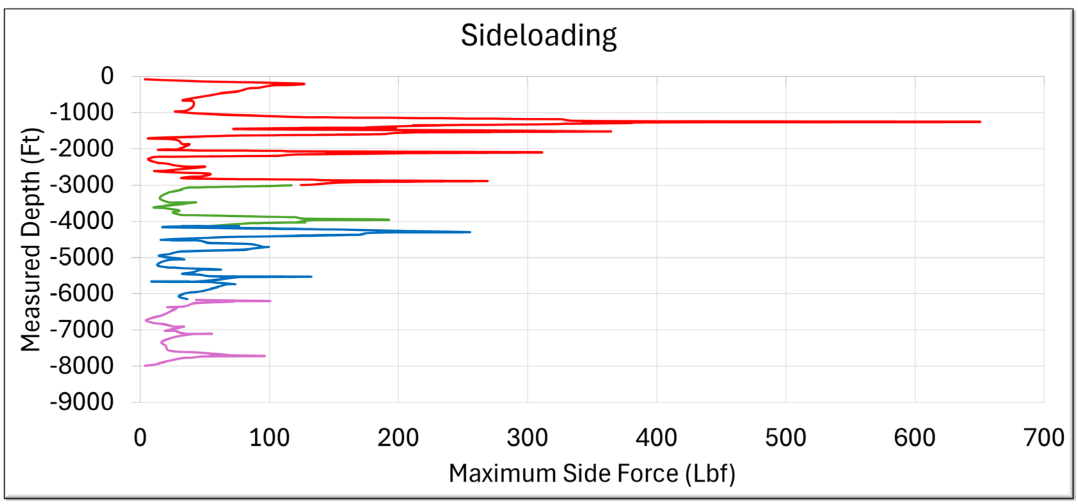

Figure 2 – Sideloading corresponding to Figure 1

An objective in artificial lift design is to optimize system longevity by reducing the effects of wellbore deviations. High well tortuosity subjects rods and other downhole equipment to sideloading forces that can cause premature wear and damage to rods and tubing (Band et al., 2017). Coupled with pump inefficiencies, pumping systems may tend to have shorter lives. To extend the life of ALS in highly deviated wells, designs must incorporate methods that distribute wear, reduce mechanical stresses, and ensure consistent pump efficiency.

One approach is to analyze high-resolution wellbore survey data, such as Gyrodata, which provides detailed measurements of tortuosity thereby providing an engineer with information about sideloading and effective tool diameter (Shoup et a., 2020). However, considering the widespread use of measurement while drilling (MWD) data, the necessity of additional high-resolution surveys may be limited. Instead, leveraging available wellbore data to inform ALS design adjustments could offer a more cost-effective and practical solution for optimizing SRP longevity.

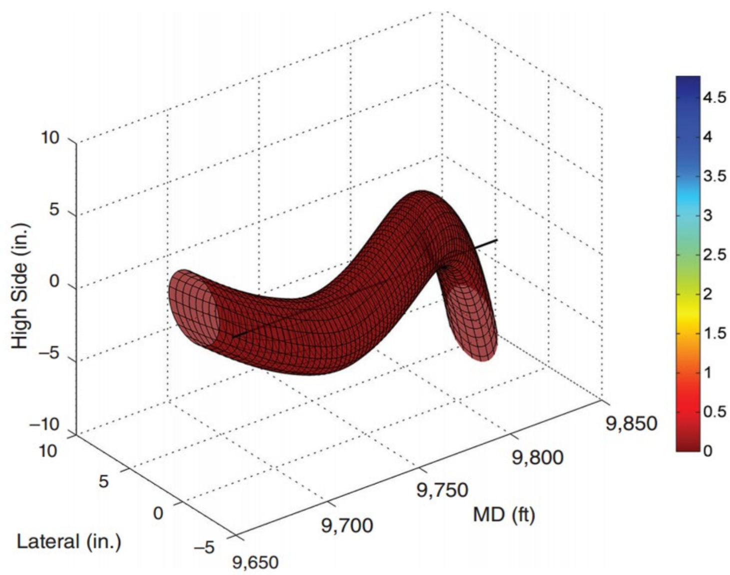

Figure 3 – 3D image of Gyrodata (poor/low effective diameter)

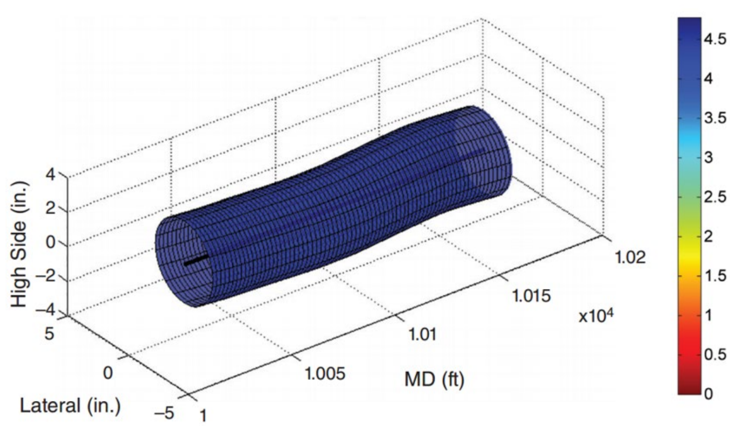

Figure 4 – 3D image of Gyrodata (desirable/high effective diameter)

INTRODUCTION

Wellbore tortuosity refers to any deviation from a straight well path. These deviations encourage contact between production equipment and the wellbore, leading to wear and increased operational costs. The severity of these effects are high in pumping ALS applications, where excessive sideloading can shorten the lifespan of rods and tubing (Jegbefume et al., 2018). Furthermore, an inefficient pump can cause similar effects from buckling the rods, so its efficiency is important to study as well.

Standard survey data collected during drilling typically provides directional information at 100 ft intervals, offering a general overview of well trajectory. High resolution surveys like those performed using Gyrodata provide measurements at much tighter intervals, allowing for a more precise assessment of wellbore curvature. This level of detail may enable an engineer to tailor an ALS designed to better accommodate the wellbore conditions, preparing to reduce wear and improving overall system performance (Shoup et al., 2020).

A well-designed SRP system ensures long-lasting, cost-effective operation by adapting to well-specific conditions such as DLS and sideloading. Since SRP applications usually extend a well's production to its economic limit, careful system design is crucial for maximizing efficiency, reducing maintenance requirements and maintaining commercially viable production rates (Cortines & Hollabaugh, 1992).

PROPOSED ROD SYSTEM STRATEGY

To overcome the challenges associated with highly deviated wells, the following rod system strategy has been developed. Each component plays a role in mitigating mechanical stress, wear, improving pump efficiency, and extending system longevity:

- Deep Setting of Pump – Ensures complete pump submergence (Pankaj et al., 2018).
- Black Mamba Rod Guides – Distributes sideloading across the entire rod string.
- Long Stroke Pumping Unit – Limits reciprocations, reducing mechanical stress and improving efficiency (Spivey & O'How, 2018).
- Rod Rotator – Promotes uniform rod wear to prevent localized failure around rod body (Treilberg & Furr, 2022).
- WhaleShark Downhole Separator– Limits gas interference by enhancing gas separation efficiency.
- Pump Off Controller – Ensures full pump fillage by optimizing stroke timing (Kolawole et al. 2019).
- Casing Gas Compressor – Reduces backpressure in the annulus, enhancing fluid movement into the pump.
- General Sand Mitigation – Prevents pump damage by controlling solids production and erosion.

DISCUSSION

SRP design requires careful consideration of wellbore conditions such as tortuosity to slow equipment wear and maintain a desirable fluid delivery. Application and the proper combination of equipment available to an engineer will allow for these goals to be achieved. The proposed strategy for rod pumping designs incorporates several different techniques and pieces of equipment that can be utilized to sustain production performance and extend the total economic life of a well. Without delving too deeply into capital expenditure, introducing and implementing strategies discussed here may yield a system that requires less workovers and higher recovery before a well is abandoned.

Deep Setting of Pump – Full Submergence

Proper pump placement is essential for maintaining efficiency and minimizing gas interference. By setting the pump deep enough to ensure full submergence, the hydrostatic pressure of the fluid column keeps free gas in solution, preventing gas lock and erratic pump behavior. Partial submergence can lead to incomplete pump fillage, slugging, and mechanical inefficiencies, all of which interfere with production and increase equipment strain.

Black Mamba Rod Guides – Sideloading Distribution Along the Entire Rod String

Rod guides are critical for reducing rod and tubing wear in deviated wells. The Black Mamba rod guides help distribute sideloading across the entire rod string, ensuring no single section bears excessive and long-lasting contact. While certain wellbore sections experience higher sideloading than others, sideloading is still present throughout the well as can be seen in *Figure 2*. Without proper guidance, rods would continuously be worn against the tubing wall, leading to premature and possibly violent failures. The use of rod guides along the entire rod string mitigates this issue by minimizing direct metal-on-metal contact, thus reducing wear and improving overall system longevity.

Long Stroke Pumping Unit – Limiting Reciprocations

A long stroke pumping unit improves system efficiency by reducing the number of reciprocations per minute while maintaining production rates. Reducing the strokes in a cycle limits the mechanical stresses on the rods and means a more gradual loading and unloading of the rod string, preventing fatigue failures and extends equipment lifespan. Additionally, the longer, slower stroke allows more time for fluid entry into the pump chamber, reducing the chance of incomplete fillage and improving volumetric efficiency.

Rod Rotator – Uniform Rod Wear

Rod rotators play a vital role in distributing wear evenly around the sucker rods. In deviated wells, rod contact with tubing is practically unavoidable, and without rod rotation, wearing on a rod may be concentrated on specific points, leading to localized wear and accelerated failure. A rod rotator ensures that the rods incrementally turn with each stroke, preventing excessive thinning in one area and extending the life of rods.

WhaleShark (Downhole Separator)– Limiting Gas Interference

Gas interference is one of the most common problems in rod-pumping wells, often leading to gas lock, incomplete pump fillage, fluid pound, and erratic production rates. The WhaleShark gas separator mitigates this issue by allowing free gas to separate and be produced through the annulus before it can enter the pump. By improving gas separation efficiency, the system ensures more stable pump operation, enhancing overall production and reducing the risk of equipment failure due to gas related issues.

Pump Off Controller – Ensuring a Full Pump

Pump off controllers (POCs) optimize stroke timing based on real-time fluid flow conditions, preventing unnecessary cycling when the pump intake is not fully loaded. In a pump operated at a rate that exceeds the reservoir’s deliverability, the system can operate inefficiently and increase stress on equipment. A POC helps maintain optimal pumping conditions by automatically adjusting the cycle rate to match reservoir fluid delivery, such that each stroke ideally lifts a full column of liquid.

Casing Gas Compressor – Maximizing Pump Efficiency

Pressure buildup in the annulus can contribute to inconsistent pump performance. A casing gas compressor mitigates this issue by removing excess annular gas and helps with gas separation at the pump intake by reducing the pressure keeping gas trapped in solution. By lowering the pressure in the casing, the compressor enhances overall system efficiency and makes sure production rates are more consistent.

Sand Mitigation – Pump Damage Prevention

Sand screens, sand separators, tailpipe, etc. Solids production presents a significant challenge in pumping artificial lift applications, as sand and other particulates can cause erosion and mechanical damage to pump components. Effective sand mitigation strategies, including downhole sand control devices and separation techniques, help prevent premature pump failures such as a stuck or inefficient pump. Implementing these strategies reduces workover frequency and ensures continued system reliability over the well’s life.

CONCLUSION

The optimization of SRP systems in deviated wells requires a holistic approach that considers wellbore geometry, equipment longevity, and production efficiency. The proposed rod system strategy integrates multiple components, each addressing different challenges, to develop a more resilient and cost-effective artificial lift solution. Rod guides distribute sideloading throughout the rod string, mitigating wear on rods and tubing. A long stroke pumping unit reduces stroke reciprocations, lowering the frequency of stress cycles on the system. A rod rotator helps evenly distribute wear around the steel rod body, extending its usable life. Additional tools, such as the WhaleShark, pump off controller, and casing gas compressor help maintain a full pump, leading to more consistent production and a lower likelihood of fluid pound. Sand mitigation techniques contribute to long-term pump reliability by reducing mechanical damage from solids.

While this strategy presents a logical and intuitive framework for improving rod lift system performance in highly deviated wells, further study is necessary to quantify its full effect under varying well conditions. The components suggested in this study, all working together, may contribute to greater system longevity and reduce workover frequency. However, cost-benefit analyses and field trials would be required to validate these optimizations on a broader scale. By leveraging these design considerations, operators and engineers can refine artificial lift strategies to better align with well conditions and production goals.

REFERENCES

Band, J., Jegbefume, O., Ledroz, A., Weston, J., & Thompson, J. (2017). *Analysis and Quantification of Wellbore Tortuosity.* Society of Petroleum Engineers. https://doi.org/10.2118/173103-PA

Cortines, J. M., & Hollabaugh, G. S. (1992). *Sucker-Rod Lift in Horizontal Wells in Pearsall Field, Texas.* Society of Petroleum Engineers. https://doi.org/10.2118/24764-MS

Jegbefume, O., Bang, J., Ledroz, A., & Shoup, R. (2018). *Rod-Guide Placement Based on High-Resolution Tortuosity Analysis of Production Tubing.* Society of Petroleum Engineers. https://doi.org/10.2118/190935-MS

Kolawole, O., Gamadi, T., & Bullard, D. (2019). *Comprehensive Review of Artificial Lift System Applications in Tight Formations.* Society of Petroleum Engineers. https://doi.org/10.2118/196592-MS

Pankaj, P., Patron, K., & Lu, H. (2018). *Artificial Lift Selection and Its Applications for Deep Horizontal Wells in Unconventional Reservoirs.* Unconventional Resources Technology Conference. https://doi.org/10.15530/urtec-2018-2875180

Shoup, R., Boltz, J., & Forrester, S. (2020). *High-Resolution Wellbore Tortuosity Logs Improve Completion and Production Equipment Placement.* Journal of Petroleum Technology. https://doi.org/10.2118/1120-0041-JPT

Spivey, S., & O'How, D. (2018). *Long-Stroke Rod Pumping Systems (LSPS) in High-Volume Unconventional Applications.* Society of Petroleum Engineers. https://doi.org/10.2118/192497-MS

Treilberg, T., & Furr, B. (2022). *Wireless Sensor Technology to Monitor Rod Rotator Performance.* Society of Petroleum Engineers. https://doi.org/10.2118/209767-MS

Villarreal, P., Morales, D., & Briceno, A. (2023). *Case Study: Customized Solution Used to Successfully Set ESPs in Unconventional Wells with Complex Mechanical Geometries Where Other Artificial Lift Methods are Unsuitable.* Society of Petroleum Engineers. https://doi.org/10.2118/214736-MS

Zhao, R., Li, J., Tao, Z., Liu, M., Shi, J., Xiong, C., Huang, H., Sun, C., Zhang, Y., & Zhang, X. (2019). *Research and Application of Rod/Tubing Wearing Prediction and Anti-Wear Method in Sucker Rod Pumping Wells.* Society of Petroleum Engineers. https://doi.org/10.2118/194955-MS

ACKNOWLEDGEMENTS

I would like to express my gratitude to the following individuals from Mewbourne Oil Company for their guidance and support:

- Calum Townsend
- Dillon Welch
- Logan Craig
- Scott Lacy

Their insights and expertise contributed significantly to the development of this study.