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Paired AI with Laser Technology Leads to 30% Improvement in Downhole Drilling Motor Performance

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Abstract

Problem: Downhole drilling motor performance is significantly impacted by the power section. The power section, made up of both a coated rotor (male) and a rubber lined stator (female) component produce the RPM and torque needed by the drill bit. These components are precision fit together to thousands of an inch, and can be affected by downhole temperature, and mud chemistry. While coatings and rubber lining materials have substantially improved over the last 20 years, the concomitant precision fit methods used have not improved. This lag in fit methods leads to avoidable failures, sub-par performance, and unduly drilling cost.

Improved laser fit methods have become available over the last five years; however, these methods require significant capital expenditure upfront, specialized training, and are slower than traditional methods, leading to marginal improvement when viewed through a ROI lens. Due to these challenges the market has been slow to adopt this technology.

Solution: The advent of generative AI has led to dramatic increases in fit methods. By pairing thousands of laser measurements with AI algorithms, a model can be trained to provide the same capabilities of the laser, whilst eliminating the capital expenditure, specialized training, and process delays caused by the laser alone. These results can be empirically measured to have significant improvements in drilling motor performance and avoid unnecessary downhole failures.

Introduction

As average lateral length has nearly doubled and time from spud to TD has remained flat or even decreased, drilling horizontal wells in a single BHA run has become a pinnacle accomplishment for operators and drillers alike. This revolution in drilling optimization has been enabled by significant increases in BHA performance and reliability.

Within the BHA, no single component has improved over the past thirty years, more than the power section (Reich et al., 2003; Alattar et al., 2017). This is largely born out of necessity; for drilling time to remain static and distances to have more than doubled, then velocity (i.e. ROP) must increase. For power sections to withstand the pressures, flow rates, and usage rates required to deliver more torque, many innovations for the main components (rotor/stator) had to be developed. Advancements in elastomer chemistry and rotor length and geometry have enabled drillers to attain increased horsepower (Prawira, 2017; Izadi et al., 2019).

While the individual components of the power section have gone through a rapid rate of improvement, the processes for ensuring the precise fit between the combined rotor and stator have not seen the associated technological adoptions. This is even though higher accuracy laser measurement devices have been around for at least five years. The hesitancy within the industry to adopt laser fit tools has been due to the upfront cost of the tool, required specialized training, and is slower than the conventional methodologies. Here, we show that by combining thousands of previously laser-measured stators with trained AI-models, drillers can improve motor performance and reliability without the impacts to cost and time.

Background

For at least the past 30 years drillers have relied on the same device to measure the minor diameter (ID) of the power section. The vector-gauge tool has gained ubiquitous implementation within the industry due to its ease of use, tool reliability, and speed. While these tools are highly engineered and precise there are some disadvantages that may lead to inaccurate measurement of the stator geometry.

First, when expanded, the nodes of the vector tool are only physically touching about 7% of the undulating elastomer. Second, the vector gauge device is not stabilized independently of the user which can cause inadvertent measurement inaccuracies as pressure is exerted on the readout end of the tool. Third, the measurements themselves are only temporarily displayed on the digital readout. This becomes problematic if the end-user transcribes the measurements inaccurately and/or needs to audit those measurements.

While individually each of the three contributors to inaccurate gauge measurements may not be significant, taken together it can translate to a resulting inner diameter outside of manufacturing tolerance. Our data suggests that about 20% of new stators are outside of OEM specifications.

Within the past five years, a laser device specifically developed to measure stators has been developed that solves many of the inadequacies of the vector gauge tool. By taking up to 3,600 laser measurements a 360° profile of the stator can be produced that more accurately represents the irregular geometry of the stator. Additionally, the laser measurements are taken using a device that is independently stabilized and saved as an auditable file.

Amongst engineers, it is generally acknowledged that the benefits of the laser measurement tool are substantial, but adoption of the technology has been slow for the following reasons:

1. Upfront cost of laser system (>$75,000).
2. Required specialized training for each user and dedicated shop space.
3. Slower process when compared to vector gauge tool.

To gain the benefits but overcome the drawbacks of using the laser tool, an AI-based model has been developed that allows engineers to combine their traditional vector gauge measurements with a database of laser-measured stators. In this way, the benefits of using a laser measurement device can be ascertained without the capital expenditure and process alterations. This paper will demonstrate that:

1. There is a significant difference in which methodology is used to measure stators (vector gauge vs laser)
2. Motor performance predicted by OEMs vs observed motor performance is not typically aligned.
3. Stators measured via a laser-device improve the accuracy of motor performance prediction compared with stators measured using the vector gauge.
4. AI-based modeling can augment traditional vector gauge measured stators with thousands of laser-measured stators to produce a stator profile that is 95% as accurate as the laser-measured stator.

Approach

When comparing two unique instruments used to measure the same object it is always important to first determine if the two methodologies have different results. Approximately one thousand stators were measured using both the vector gauge and laser measuring devices and the difference between the mean stator ID (inner diameter) was calculated. Figure 1 shows that the average difference between the two-measurement systems is approximately 0.004 inches. Further, ~10% of those measured stators had a greater than 0.01-inch difference. These are significant variations to consider when the difference in a successful vs failed motor run can be due to a stator/rotor clearance of less than 0.001 inches.

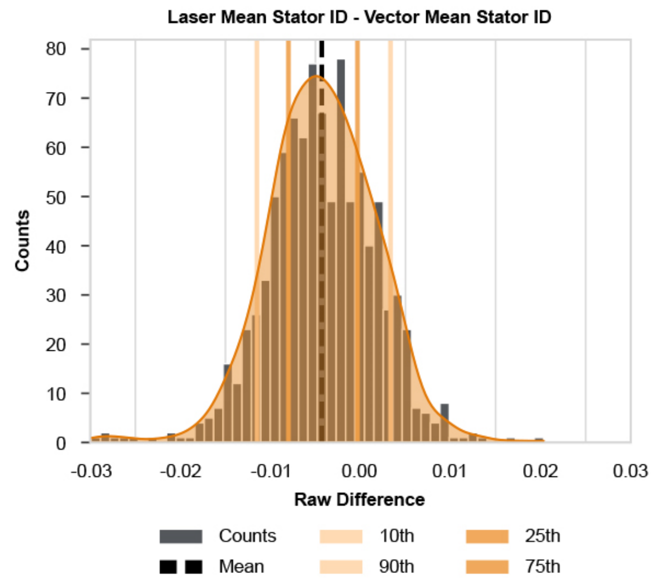

Figure 1 –Difference (in inches) of mean stator ID measured with vector gauge and laser.

The principal method drillers attempt to determine motor performance prior to use is to consult the OEM provided specification sheet (spec sheets). The OEM spec sheets can give drillers vital information like: RPM range, recommended pressure, max torque and stall pressure/torque. Most spec sheets will also provide adjustments to fit with increased temperature, estimated horsepower at varying differential pressures and flow rates. Drillers will typically consult the spec sheets to ascertain an initial recommended fit and estimation of motor performance. However, deviations in drilling conditions and equipment variabilities can prevent accurate estimations of motor performance from the spec sheets exclusively. Figure 2 shows the raw percentage difference between expected spec sheet max torque and measured max torque. For over one third of the motors analyzed there is a greater than 10% difference in expected max torque (based on spec sheet estimates) and measured max torque. The reasons for the discrepancy could be due to a variety of challenges including: inaccurate fit measurements, rotor variability (repairs and recoats) and drilling conditions (temp, mud swell, flow rate). By not properly understanding the maximum motor performance, drillers may overexert the motor leading to equipment failure or run the motor at a reduced ROP; unnecessarily increasing time to TD.

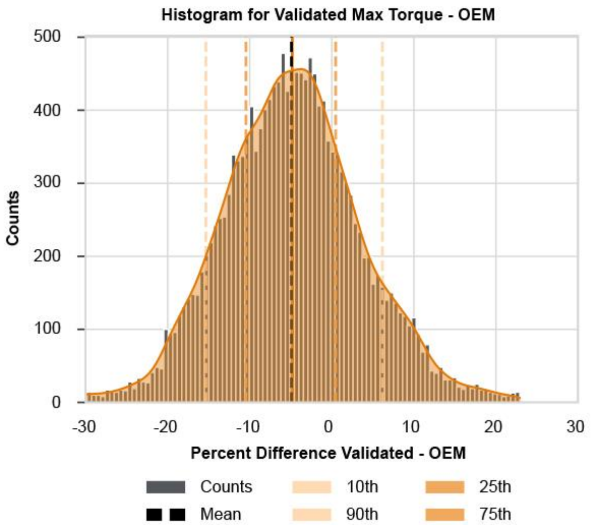

Figure 2 –Percentage difference in predicted max torque and measured max torque

The reality is that the OEM spec sheet fit recommendations are calculated based on rigorous precision engineering based on new equipment. Discrepancies between OEM provided motor performance and reality is to be expected when motors are assembled from non-new equipment and measured with less than laser precision.

The question becomes: how do we validate if either of the measurement systems are more accurate at predicting motor performance in conjunction with the estimates provided by the OEM?

In Figure 3, horsepower is predicted from OEM spec sheets where fit is calculated using vector gauge measured stators exclusively and then plotted against actual measured peak horsepower. The moderate correlation (R^2=0.612) suggests that measuring fit via the vector gauge tool does not lead to an accurate prediction of peak horsepower.

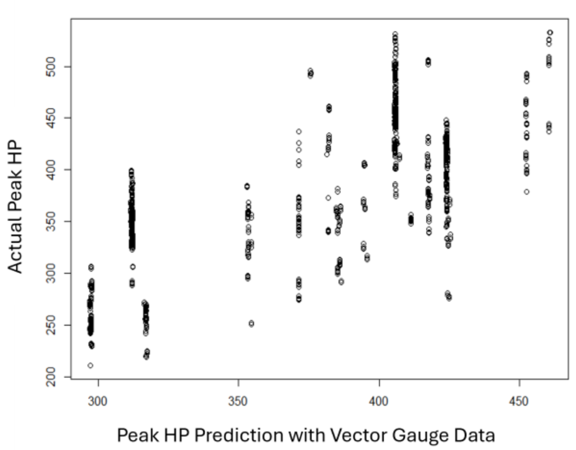

Figure 3 –Peak horsepower prediction vs. actual measured peak horsepower for stators measured via vector gauge tool (R^2=0.612).

Conversely, in Figure 4 horsepower is predicted from OEM spec sheets where fit is calculated using laser measured stators exclusively and plotted against actual measured peak horsepower (R^2>0.99).

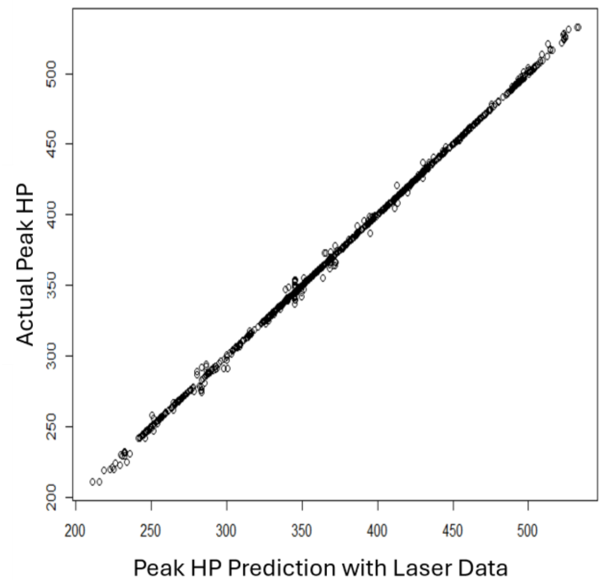

Figure 4 – Peak horsepower prediction vs. actual measured peak horsepower for stators measured via laser tool (R^2>0.99).

Clearly, stators measured using a tool that can incorporate a full 360° slice substantially increased the accuracy of motor performance estimation. The challenge for most drillers in adopting a laser measurement system is two-fold:

1. Upfront capital expenditure to purchase hardware/software/personnel training.

2. The process of laser measuring a single stator can be up to ten times longer when compared to vector gauge measurements.

Solution

Rapid advancements in generative Artificial Intelligence (AI) over the past decade have enabled a step-change in optimizing many aspects within the oil and gas industry (Koroteev and Tekic, 2021; Botao and Jiancheng, 2019). AI has already delivered economical gains in areas like well placement, operations optimization, and predictive maintenance (Mahiot, et al. 2022; Arinze, 2024). AI's ability to proactively utilize the full breadth and variability of data partners strongly within the drilling domain where reactive root-cause analysis typically dominates.

Operators and service companies have been collecting post motor-run data for several decades with the goal to understand where failures or underperformance may have occurred within the BHA. This is largely a reactive process where issues are ascertained post-motor run and any insights are applied to future runs. Of course, that motor had to be pulled out of hole (POOH) and replaced which is costly and decreases overall ROP for that well.

A generative AI model has been trained by utilizing thousands of laser-measured stators across numerous power section configurations. This model enables drillers to get the benefits of a laser measured stator without the capital and workflow impacts. The AI-trained model can ingest the standard vector gauge measurements taken by the engineer and improve their accuracy significantly.

In Figure 5, stators were measured at six different locations using the standard vector gauge instrument and then inserted into the AI-trained model to calculate a synthetic laser-measured profile. The model then combines the synthetic laser-measured profile with the rotor (OD) measurements to calculate fit. Once the algorithm has calculated fit , the OEM spec sheets are once again consulted to estimate peak horsepower and then plotted against measured horsepower. When compared to Figures 3 and 4, the synthetic AI-based laser profile is a significant improvement from purely vector gauge measured stators when estimating motor performance. Additionally, the synthetic laser-measured profile is about 95% as accurate as the true laser measured stators when predicting motor horsepower.

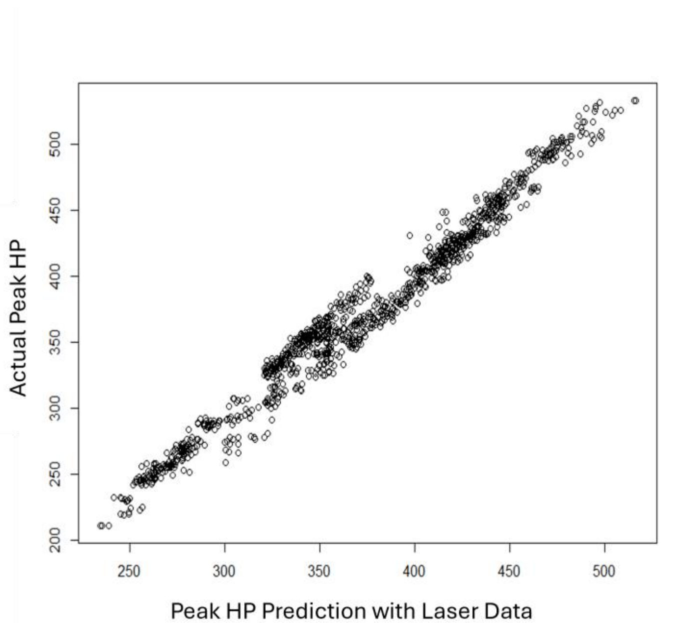

Figure 5- Peak horsepower prediction vs. actual measured peak horsepower for stators measured via vector gauge tool and combined with AI-based model.

Conclusions

The following conclusions can be derived from this work:

- Laser-measured stators offer the most precise methodology for effectively estimating motor performance.
- OEM provided spec sheets are an excellent tool for estimating motor performance but only if fit is accurately measured
- Traditional vector gauge measured stators can more accurately be measured by combining the shop measurements with an AI-trained data model that incorporates laser-measured stators.
- Drillers can obtain the benefits of a laser-measured stator at a fraction of the capital expenditure by incorporating this AI-based model into their motor build program.

Nomenclature

BHA = Bottomhole Assembly
DD = Directional Driller
ID=Inner Diameter
OD=Outer Diameter

References

Alattar, A. Mustafa, M. Applegate, N.R. et al. 2017. “New Positive Displacement Motor Technology Significantly Improves the Drilling Performance through Challenging and Abrasive Strata in Northern Kuwait.” Abu Dhabi International Petroleum Exhibition and Conference held in Abu Dhabi, UAE, 13-16 November. SPE-188937. http://dx.doi.org/10.2118/188937-MS

Arinze, Chuka & Izionworu, Vincent & Isong, Daniel & Daudu, Dominic & Adefemi, Adedayo. 2024. Predictive maintenance in oil and gas facilities, leveraging ai for asset integrity management. International Journal of Frontiers in Engineering and Technology Research. 6. 16-026. 10.53294/ijfetr.2024.6.1.0026.

Botao, Lin and Jiancheng, Gao. 2019 “Discussion on current application of artificial intelligence in petroleum industry.” Petrol. Sci. Bull. 2019, 4 (4), 403– 413.

Izadi, M. Tabatabaee, M Ghomi. and Picheraghi, G. 2019. "Mechanical Strength Improvement of Mud Motor’s Elastomer by Nano Clay and Prediction the Working Life via Strain Energy," International Journal of Engineering, 32 2: 338-345.

Koroteev, Dmitry & Tekic, Zeljko. 2021 “Artificial intelligence in oil and gas upstream: Trends, challenges, and scenarios for the future.” Energy and AI, Vol 3 (100041). https://doi.org/10.1016/j.egyai.2020.100041.

Mahiout, Mohamed Said, Al Enezi, Faisal Naif, Santoso, Gagok Imam, and Mohammed Satti Ali Elhaj. 2022 "Artificial-Intelligence-Based Well Placement Look Ahead Concept." ADIPEC, Abu Dhabi, UAE, October 2022. doi: https://doi.org/10.2118/211752-MS

Prawira, Atma & Rini, Etiko. 2017. “Size and configuration of mud motor drilling affects the optimum power outputs.” Engineering Solid Mechanics. 5. 93-102. 10.5267/j.esm.2017.3.003.

Reich, M., Oesterberg, M., Regener, T., Kent, D., Nawfal, N., Al Khames, S., et al. 2003. “New Performance Motors Set New Benchmarks in Drilling Performance.” SPE/IADC Middle East Drilling Technology Conference and Exhibition. Society of Petroleum Engineers. Oct 2003. SPE-85338-MS.