IT'S ALL ABOUT THE END FITTING 2: LOAD/COMPRESSION HANDLING & DESIGN FLEXIBILITY

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ABSTRACT

In recent years, there have been advancements in fiberglass sucker rods (FSR). The published ratings have increased by over 20 percent with some manufacturers reporting even higher ratings. Field trial data for FSR is presented in this paper to show results that were accumulated over a continuous operational period. The test well was upgraded to the latest release of FSR which reduced the fluid over pump and increased production. This paper will discuss proper design steps which include the importance of well specific information. The dynamics of the well bore are also a topic of discussion as the latest FSR load ratings allow opportunities for substitution of rods which reduces overall costs. How FSR Series 100 and Series 200 handle compression will also be discussed, along with supporting data that will correlate the increase in strength to a measurement of compression handling within the rod string.

INTRODUCTION

Over the course of the past three years, FSR product performance parameters have significantly increased when compared to prior releases. Endurance Lift Solutions, LLC (ELS) went from Series 100 (Fiberod) to the current Series 200 end fitting. This new product development was described in detail in the paper titled "It's All About the End Fitting: Advanced Testing and Design Improves Fiberglass Sucker Rod" and was presented in the spring of 2015. The paper focused on the development process and design that delivered a product with 25 percent improvement in the working load range, a 30 percent increase in the maximum load capacity while controlling potential failure modes [1].

Since the launch of the FSR Series 200, the product has been widely installed throughout North America (Permian Basin, Mid-Con, Bakken) with positive feedback from our customers. One of the installations took place as a part of the field trial/evaluation phase with a customer that was willing to provide ELS access and ability to collect rod samples at predetermined production periods. These samples were later evaluated and tested internally at the ELS testing facility located in Big Spring, TX. This paper provides an update on the final stage of the design process by presenting field data accumulated from the field trial samples.

Additionally, work has continued in the development and understanding of the full potential of the FSR. Part of that work was to optimize the steps of designing a robust FSR string by increasing the bottom minimum stress which minimizes the potential of compression scenarios [2]. This paper will also discuss a method for understanding compression in a FSR string along with a summary of the results of in-house compression testing.

FIELD DATA

The FSR Series 200 rods were installed in the test well on April 29, 2015 as part of a trial/evaluation phase and are still operating today. The rod string previously installed in the well consisted of 1-inch FSR, 0.875-inch steel sucker rods (SSR), 1.5-inch sinker bars, and a 1.5-inch plunger. The predicted calculated production of 344 BFPD was simulated as a vertical well operating at 11.4 strokes per minute (SPM). The well actually did not produce more than 270 BFPD and the downhole stroke was 27 percent less than what was calculated. The reduction in production and downhole stroke can be attributed to the exclusion of the well deviation information from the simulation.

The customer agreed to change the rod design and to increase the pump bore to optimize the well by decreasing the excess fluid level in the annulus of 1,880 feet above the pump. The trial rod design consisted of unguided 1.25-inch FSR, 1-inch SSR, and 1.5-inch sinker bars. The plunger was sized up to 1.75-inch and the pump was set at approximately 5,000 feet as in previous configuration. The pumping speed was set at 9.5 SPM and accumulated approximately 8.3 million cycles over the course of twenty months. The surface stroke of 123-inches generated a gross pump stroke of 114-inches at the pump (as predicted). The increase of the pump bore size resulted in a prediction of 343 BFPD. The well test with the new configuration produced 334 BFPD, which was within 2.6 percent of predicted production. This rate ultimately reduced the fluid to a stable level of 256 feet above the pump, allowing the customer to achieve increased production of 64 BFPD.

Throughout the test period a number of rods were pulled and replaced at different locations within the FSR Series 200 taper. The locations were in the top, middle and bottom of the FSR portion of the string and were selected based on loading differentials as related to top maximum stress and bottom minimum stress. The replacement rods were installed at the top portion of the rod string and omitted for the next extraction of test samples. This periodical collection of rod samples from the rod string took place at approximately five and twenty months of continuous operation as agreed to with the customer. These rods were then subjected to inspection and evaluation for any degradation in performance. The inspection consisted of a visual assessment, the measurement of the gap between the epoxy and the end fitting, the swelling of the end fitting and pin elongation. The evaluation consisted of one-time-pull-to-failure (OTPTF) or ultimate load testing and internal cavity inspection.

All measurements of the sampled rods showed no dimensional change. The holding capacity as evaluated by OTPTF showed no loss in performance when compared with production line samples.

ROD DYNAMICS

Arguably, a 1-inch FSR design should deliver the required production volume and remain within the recommended load range. However, with the lack of input data, such as a deviation survey, the designs are left with a high degree of uncertainty and thus the actual production volume can differ significantly. A more robust rod string configuration utilizing 1.25-inch FSR and more weight (larger SSR) reduces uncertainty and the design's sensitivity to omitted or missing input parameters. The predictive rod design software displays stress levels for each taper which is important for evaluating reliability of the design. These predicted results fall short when addressing underestimated production due to a loss of downhole stroke. The appropriate product selection should not be based on the predictive software alone but should also take into the consideration the historical production output and how closely it correlates with the predicted values.

TESTING COMPRESSION

ELS, performed compression testing as a part of continuous product improvement and understanding the full potential of FSR Series 200 rods. This testing took place in the ELS Big Spring laboratory focused on simulating well scenarios where the rods were exposed to recoil and/or compression loading. The test setup consisted of a tensile machine (capable of loading a specimen up to 225,000 pounds), a pneumatic quick release, an anchor point (for recoil loading to act against), and newly produced FSR Series 100 and Series 200 rods (both 6-feet and 37.5-feet lengths). The published recommended stress range diagram for ELS fiberglass rods, as seen in Figure 1, shows the bottom minimum stress lower limit at 1250 psi [1]. However, scenarios exist that could drive the bottom minimum stress below the recommended limit and/or into compression. Any fiberglass rods operating at those stress levels can experience forces within the cavity of the end fitting that could be detrimental to the wedge mechanics and the integrity of the epoxy. In the laboratory, the recoil forces were selected (16k, 26k, 31k, and 51k pounds) to mimic recoil loads generated during a shear tool failure.

A graphical representation of the setup can be seen in Figure 2. Five test specimens were preloaded to each of the specified recoil loads. Once the set load was reached the quick release was activated and the rod would recoil into the hard anchor. After completion of these steps the specimen was then tested OTPTF and both elongation and ultimate load data was recorded. The aggregated OTPTF loads were then plotted with respect to the recoil load and compared against the baseline OTPTF laboratory data for the FSR Series 200. The 6-foot samples of 1.25-inch FSR Series 100 and Series 200 were selected as the initial tests showed no difference in results due to a specimen's length.

A graph of the results, normalized by FSR Series 200 ultimate load, can be seen in Figure 3. As anticipated, the recoiled FSR Series 200 compared to Series 100 rods pulled more consistently and had less degradation in load handling capacity after a recoil event. For example, results for the batch of 16k pound recoil specimens showed a 5.7-times improvement in the relative performance regarding the load handling capacity for the FSR Series 200 versus Series 100. Furthermore, none of the recoiled specimen yielded the original preload established when setting the wedges per API.

CONCLUSION

Over the course of the past 3 years there have been advancements in fiberglass sucker rods which have delivered an improved product with increased performance characteristics when compared to previous FSRs. The Endurance Lift Solutions team continues to research the enhanced potential of the recently developed FSR Series 200 rods. The field test data showed that 8.3 million cycles for the given well parameters resulted in zero loss of product performance or load handling capacity. All inspections and measurements were within the manufacturing tolerances. The product continues to perform as intended and ELS continues to cooperate with the customer to monitor the FSR Series 200 performance.

Operating parameters within the wellbore may create a scenario when continuous or one-time recoil or compressive load is applied to the rod taper. Within the ELS laboratory, a test scenario was created to study this type of compression event and how it affects the overall performance of the product. The results of the simulated recoil events confirmed that compressive loads can impact the performance of fiberglass rods. However, the reduction in performance can be greatly abated by use of the FSR Series 200 rod. ELS operating procedures instruct that any rods subjected to such loading shall be inspected and/or tested prior to redeployment into the wellbore. Single event recoils within the range of 16k pounds have a minimal impact on the load handling capacity for the FSR Series 200.

REFERENCES

1. Gernentz, R., Hricisak, K, & Alzoubi, M. (2015). It's All About the End Fitting: Advanced Testing and Design Improves Fiberglass Sucker Rod. Southwestern Petroleum Short Course, pp. 36-44.
2. Shigley, J. E. & Mischke, C. R. (2001, 6th edition). Mechanical Engineering Design, Mc Graw Hill Higher Education, New York, NY, pp. 396-402.

APPENDIX

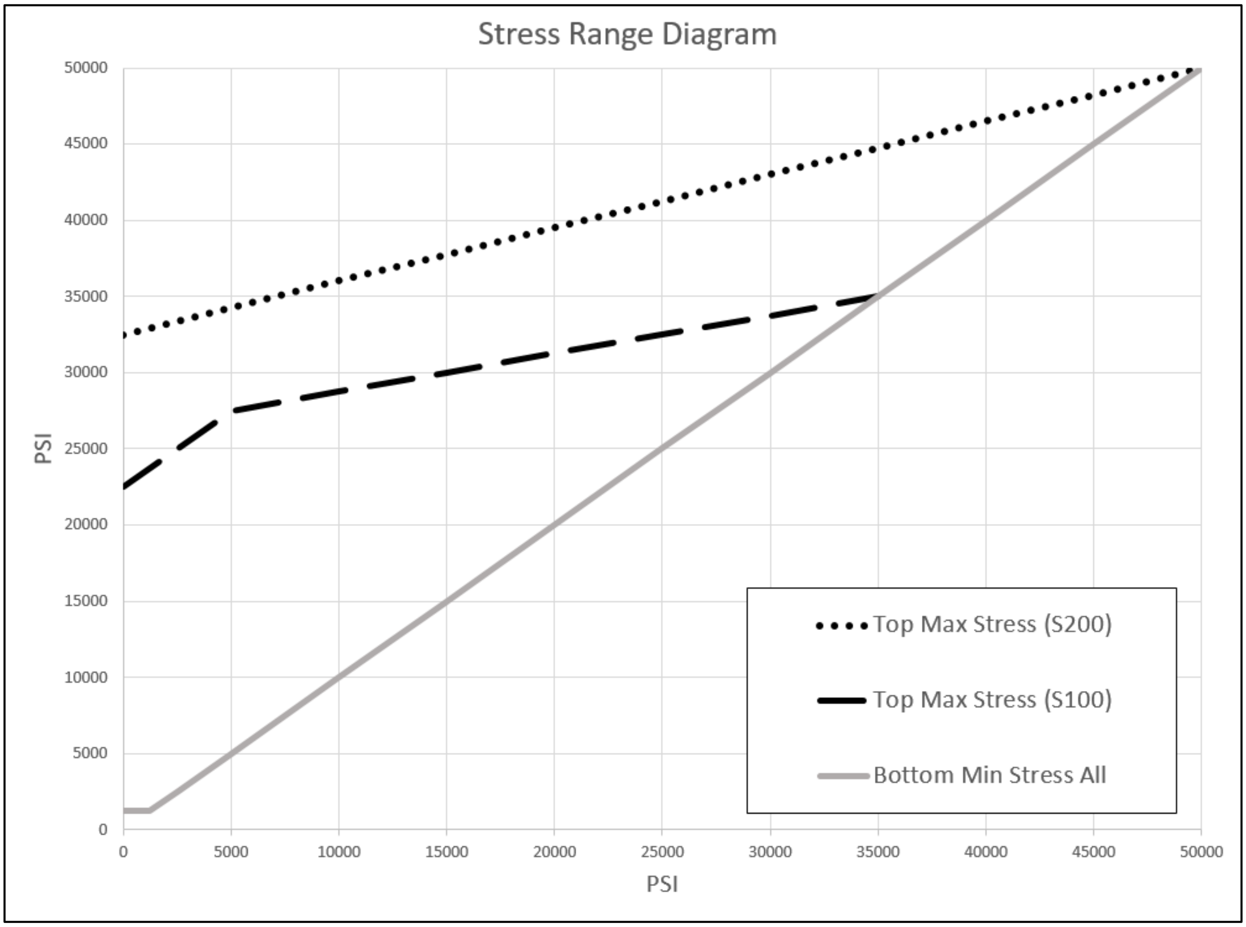

Figure 1 - Stress Range Diagram

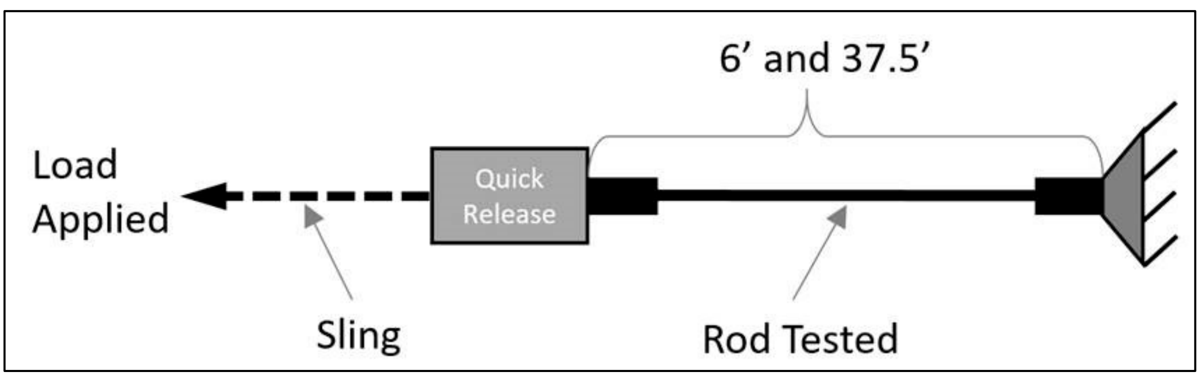

Figure 2 - Compression Testing Setup

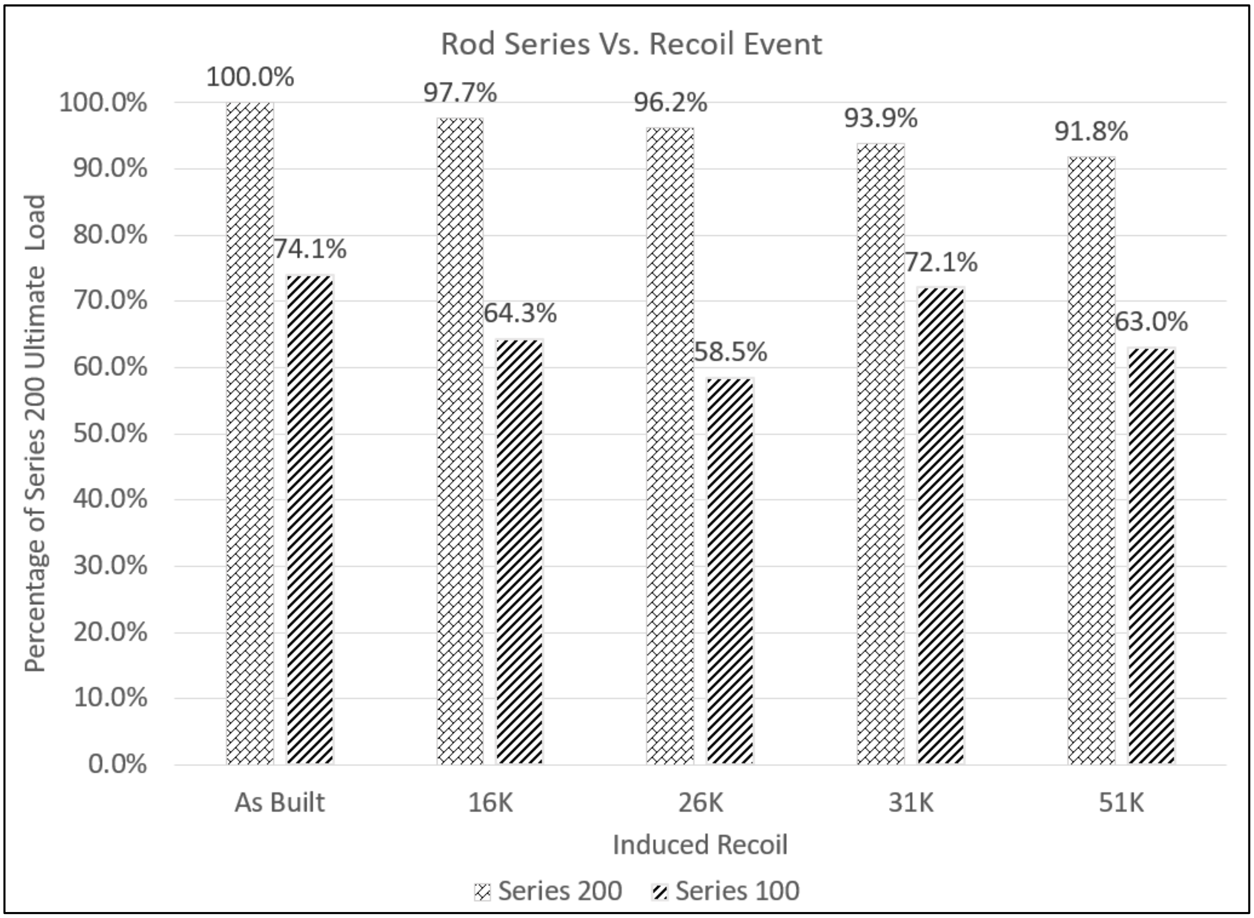

Figure 3 - Compression Testing Results