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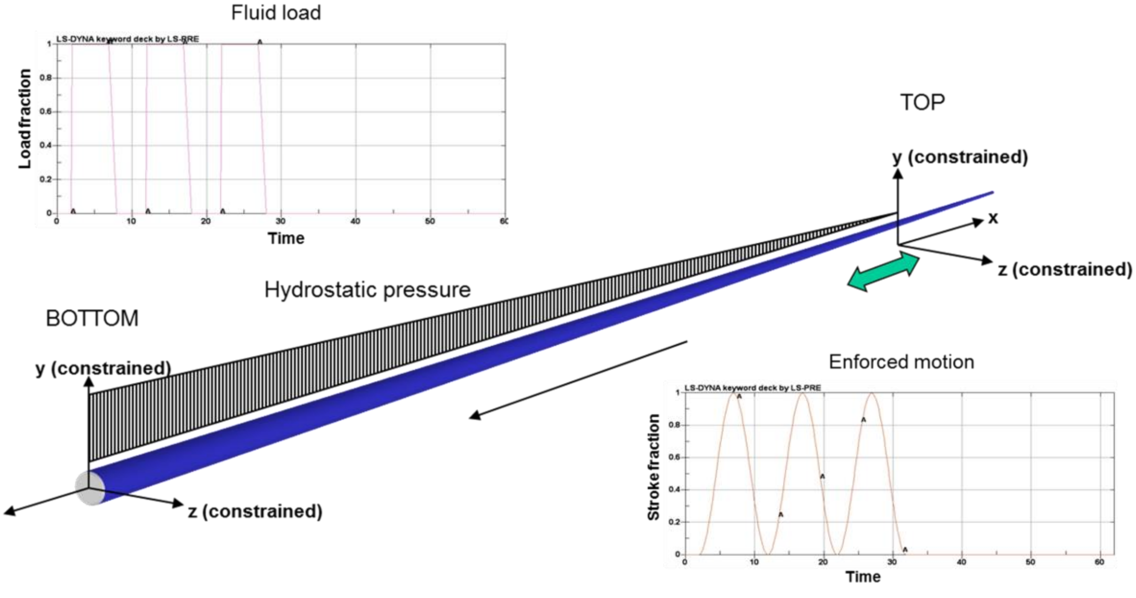
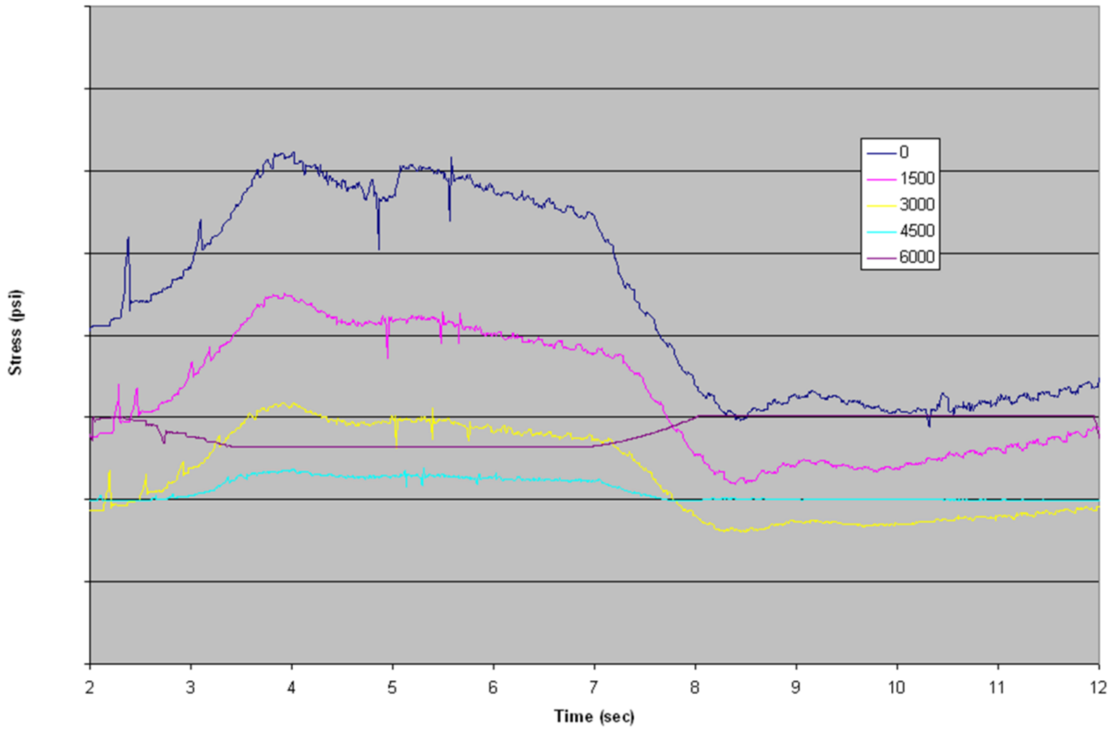
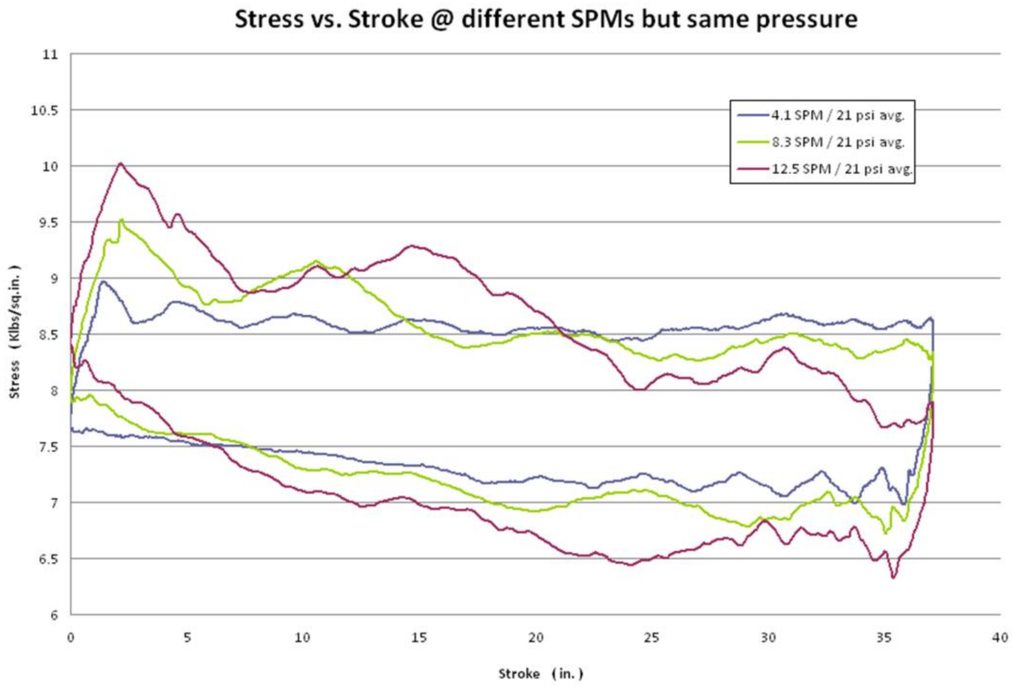
CTLift Systems and Starboard Innovations, LLC., collaborated on a multi-faceted project to develop operating life predictions for the CT Lift application. Starboard's engineering capabilities in simulation, analysis and testing provided great value to the development of the project. The finite element (FE) simulations, fatigue testing, field testing, and data analysis helped form the development of application software for predicting fatigue life as well as the length of the CT in compression.

The initial efforts of the project were to develop an FE simulation of the CT Lift operation. Doing so would allow an understanding of the cyclic stresses that result from the dynamic system operation. Starboard used LSDyna explicit FEA time simulations, with top drive and pump boundary conditions efficiently, but accurately, configured. Fluid loads were applied at the pump piston and hydrostatic and gravity loads were distributed along the CT. Top drive displacement was enforced to generate sinusoidal motion. The figures show the model set up and an example set of predicted CT stresses for different locations along the string.





Initial FE simulations produced stress values to be used in alternating/mean fatigue estimates. These FEA predicted stress cycle results were then compared to well test stress data, in an effort to calibrate the FEA results. The well data and simulation model data matched fairly well for predicted peak stresses, though the model was slightly conservative on maximum stress. Starboard concluded that dynamics can be a large contributor to the minimum and maximum cycle stresses and will be an important factor to consider in fatigue life analysis. A sample of the field data is shown in the figure.



In order to evaluate fatigue life for the CT material, tubing samples needed to be tested to failure. An array of samples was tested and a fatigue life curve was defined. Consideration was also given to welded joints. The stress cycles selected were based on model-predicted, worst-case stress conditions. The combination of validated stress predictions and measured fatigue life properties allows for more accurate life predictions to be made for each job.

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Figure 9. Failure location for specimen 8.

Figure 10. Failure location for specimen 9.

To bring the analysis of FEA simulations, fatigue testing, and field testing together, Starboard Innovations developed software for CT Lift job design and planning. The software estimates the number of cycles of life expected for a given CT Lift application design based on an array of job parameters. For example, consider the following job set-up. A 5000 ft vertical well with 1.25" CT having a 0.134" wall thickness. Water is assumed to fill the tubing annulus to surface. The pump has a 1.50" bore and is stroking at 5 spm. The model predicts the upstroke and downstroke loads and uses this to calculate the cyclic stresses. A dynamic correction factor is applied. The resulting fatigue life is predicted to be greater than 10 million cycles, or essentially infinite fatigue life for metals. This equates to about 4 years of operating life, but likely much more. The model also predicts a length in compression of 637 ft for this job.