SURFACE DIAGNOSTICS AND ANALYSIS IN OPTIMIZATION TECHNOLOGIES FOR SUCKER ROD PUMP LIFTED OIL AND GAS WELLS

Ian Nickell
ChampionX

ABSTRACT

Sucker rod pumping is a common artificial lift method for oil and gas wells in the United States. For decades when using this method, well analysts and production engineers looked at surface and downhole dynamometer cards to diagnose various downhole and surface equipment issues. In more recent years, advantageous rod pump diagnostic software tools have helped train well analysts and production engineers in the analysis of downhole dynamometers cards using comprehensive libraries of known behavior. Unfortunately, the same libraries do not exist for surface dynamometer cards. Without these libraries, diagnostics are based solely on information captured in the downhole dynamometer card. While a majority of data used for analytics and diagnostics can be found in the downhole dynamometer card, a more comprehensive analysis can be done by looking at both the downhole and surface dynamometer cards.

Recently, great strides have been made to analyze data and patterns not only found in downhole dynamometer cards, but also surface dynamometer cards. Dynamometer card analysis experts agree that in some cases pump tagging and shallow friction are more visible in the surface dynamometer card than the downhole dynamometer card. Based on these expert opinions, algorithms have been developed that leverage data science tools and statistical methods to better detect both shallow friction and pump tagging problems that are visible in the surface dynamometer card well before they can be seen in the downhole dynamometer card, especially for deep wells.

These new algorithms will be additional tools to help well analysts and production engineers more quickly and effectively analyze dynamometer cards and optimize production for the sucker rod pumping system. While current downhole analytical software does provide great benefits to users, adding these algorithms will provide a more robust and effective dynamometer card analysis.

INTRODUCTION

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MATERIALS AND METHODS

Analysis Using Downhole Dynamometers

Because downhole dynamometer cards have a well-documented library of shapes, downhole dynamometer card diagnosis boils down to interpreting data based on a small group of known card shapes. Although pump depths and production rates may vary, almost all downhole dynamometer cards have consistent shapes that can be used to interpret and diagnose pump problems. This enables simple and effective diagnosis of thousands of wells using a limited library for comparison.

The primary limitation of the downhole dynamometer card is that it's calculated from the measured surface card. This means it's only as good as the method for calculating the downhole card, and most methods of calculating downhole dynamometer cards do not consider certain variables like deviations or fluid friction. As the wells grow in depth and the loads continue to increase, detecting anomalies in the downhole card becomes more challenging. Even with significantly deviated wells, there is still value in looking at the downhole dynamometer card. However, it is increasingly necessary to include the surface card to make analysis more complete.

The primary focus of this paper will be using surface dynamometer cards to detect shallow friction and pump tagging, which happens when the pump is incorrectly spaced and contact is made between the plunger and the bottom of the pump at the end of the downstroke. As previously mentioned, downhole dynamometer cards have a known library of card shapes that can be applied for every downhole dynamometer. This also applies to cards with shallow friction and pump tagging. However, as the wells become deeper, the ability to detect these conditions using the downhole dynamometer card becomes increasingly more difficult. This is especially true when trying to detect these conditions using diagnostic software. It's important to recognize the limitations of software and data in these cases. Since some variables such as deviations and fluid friction are ignored in downhole dynamometer calculations, it's important to also consider the surface card. This will help provide the most accurate analysis for the overall health of the well.

Analysis Using Surface Cards

Analyzing and interpreting surface dynamometer data to understand downhole pump conditions requires experience and expertise in surface dynamometer diagnostics. When analyzing, it's important to recognize patterns and understand how downhole and surface conditions affect the shape of the surface card.

Because the shape of a surface dynamometer card depends on several variables – like speed, depth, rod material, rod size and plunger size – there is not a single library of card shapes that describe the well condition. The varying shapes of a surface dynamometer card can make it particularly difficult for diagnostic tools, which typically use pattern-matching technology to diagnose possible issues with dynamometer cards.

Even for experts, using a surface card to determine issues like valve leaks or to infer pump fillage can be very difficult. Therefore, it's even more difficult to train a software program to diagnose these dynamometer cards. While certain pump conditions can be difficult to understand looking at a surface dynamometer card, there are some specific traits that can be homed in on in order to better understand pumping issues. Specifically, pump tagging and shallow friction have very obvious attributes in surface dynamometer cards.

Trying to train a software program to diagnose dynamometer cards has triggered innovative ways of analyzing dynamometer card data. As previously mentioned, pattern matching is one of the most common ways of diagnosing downhole dynamometer cards. This involves having a library of already diagnosed dynamometer cards and then matching those cards to the actual calculated cards in order to analyze the downhole dynamometer cards using software. However, this type of analysis is incredibly difficult to do with surface cards because there isn't an existing library of card shapes. Instead, a statistical analysis of the card shape must be performed to find specific attributes in the surface card to understand if there are markers for suboptimal performance in the surface card. This allows the software program to find the specific attributes used to diagnose pump tagging or shallow friction without having to match the entire surface dynamometer. This type of analysis has opened the door to even more future surface dynamometer card diagnostics.

Analysis Theory

When analyzing dynamometer data – whether it's surface data or downhole data – there are specific characteristics that are important to identify. Specifically, in downhole dynamometer data there are well-documented and known shapes for a variety of pump conditions. The known downhole pump shape has specific characteristics that are displayed for tagging down as well as shallow friction. When the pump is tagging on the downstroke there is typically a distinct signature in the downhole card that shows the load decreasing greatly on the downstroke.

Figure 1 is an illustration of the pump tagging at the end of the downstroke in the downhole card. In this case, the pump is hitting down in the last ten inches of the stroke and the abrupt decrease in load on the downstroke is how this can be known. This occurs because part of the pump is being physically kept from moving down causing a force pushing upward reducing the load on the pump rod.

Likewise, shallow friction can also be detected on the downhole card in Figure 2. This comes in the form of increasing loads on the upstroke and downstroke, as well as a decrease in load at the end of the upstroke and an increase in load at the end of the downstroke. These load changes at the end of the card are caused by pump loads returning to where they would be without the effects of shallow friction on the downhole card.

Although these examples make these characteristics seem easy to detect, in many cases they can be much more subtle, and when adding other characteristics from other possible pump problems, it can be less obvious that these problems are occurring by only looking at the downhole pump card.

Looking at only the downhole card can be limiting. That's why to understand pump tagging and shallow friction, it's also a good idea to look at the surface card. In the surface card, tagging can be diagnosed by observing a sharp increase in load at the end of the downstroke or a sharp decline in load at the beginning of the upstroke, which is where it occurs most often. These loads are very abnormal, especially when conceptualizing why this could be happening. In order for the load to drop so sharply at the beginning of the upstroke, the load has to be moving in the direction that the pump is traveling in order to cancel out some of the load that the rods and fluid should be putting on the surface equipment. The effect from the tagging can be seen throughout the rest of the upstroke as the card shape becomes wavy or even jagged.

Shallow friction can also be detected in the surface card by looking at the beginning and end of the pump stroke. When shallow friction is occurring, the ends of the dynamometer card will become increasingly flat. The flat loads at the beginning and end of the card are a clear indicator of shallow friction. The magnitude of the friction can be measured by observing how long the flat part is at the ends of the cards. For the larger flat portions, there is more friction. This is because at the end of the strokes, as the load transitions from moving the pump in one direction to the other, the friction load must be transferred to the other direction as well, resulting in an increased change of load that is essentially equal on the upstroke and the downstroke.

Figure 3 shows pump tagging in the surface card as well as the downhole card.

RESULTS AND DISCUSSION

Case Study Examples

Case study #1 is an example of tagging that can be seen more clearly in the surface card than in the downhole card. This is a Bakken well that is greater than 9,000 ft. deep. At this depth, the load difference is hard to notice since the tag is subtle in the downhole card (Figure 4). However, on the surface card, a dramatic load shift at the beginning of the upstroke is observed and this clearly points to tagging.

Another interesting indicator for this well is the stroke length. The stroke length increased nearly ten inches, which can also point to a possible tag. The apparent gas interference seen in Figure 5 where the two cards are overlaid is causing the stroke length to increase and create a tag. When comparing the cards for the well when it's tagging and when it's not tagging, it's clear that there is a major difference in the card shapes, and the perceived tag on the surface card is confirmed when looking at the downhole card.

Case study #2 is another example of tagging in a Bakken well that is greater than 9,000 ft. deep. When looking at the card overlaid, once again it is obvious that at the beginning of the upstroke the surface card (Fig. 6) has a very quick and immediate load drop. In this case, the tagging can be confirmed when looking at the downhole card as well. Again, the tagging is much clearer when looking at the surface card. Without first detecting a tag in the surface card and then validating this by looking at the downhole card, the tag may have gone unnoticed. Another way to catch the tag overlay the two downhole cards (Figure 7). Although this is an effective way to verify, it is very difficult to train software to do this so diagnosing this tag in the surface card is the optimal approach.

Case study #3 is similar to the first case study in many ways. However, this is a Permian well that is only around 8,600 ft. deep. This card exhibits increased stroke length and has very similar gas interference. The tagging, once again, is not blatantly obvious in the downhole card (Figure 8) as it is with the surface card. The subtle load change is only clear when looking first at the surface card or when overlaying the downhole card (Figure 9) where the pump is tagging and comparing that card to a card taken from a stroke where the pump is not tagging. The tagging seen in the surface card and diagnosed by the software can be confirmed by looking at the downhole card. This is another clear situation where downhole dynamometer card analysis alone is not sufficient, and analysis of the surface card must be done as well.

Case study #4 is an example of shallow friction detected using surface card analysis that is less obvious if only looking at the downhole card (Figure 10). This is a Permian well that is over 9,000 ft. deep, and if only looking at the downhole card, the pump condition is not obvious. Although it appears that there could be shallow friction, there is also evidence that there could be problems with the valves as well. The rounded corners of the card certainly give the appearance of pump wear, leaking traveling and standing valves, or shallow friction. A traveling valve or plunger leak combined with shallow friction is the likely cause.

Although the plunger or valve leak cannot be fixed without a workover, the shallow friction problems can be resolved by simply adjusting the stuffing box or changing the chemical program for the well. The surface card is key in detecting and validating the shallow friction in this case with software.

Case study #5 is another case of classic shallow friction on the surface card with the flat ends on either side (Figure 11). The flat ends are an obvious sign of shallow friction. However, looking only at the downhole card, it is difficult to tell what caused the rounding of the edges. There is likely gas interference, but there is also a chance that the rounding is due to a standing valve leak.

By looking at the surface card and seeing the obvious signature of shallow friction, this validates that the shallow friction attributes seen in the downhole dynamometer card are in fact due to shallow friction. This also demonstrates that there aren't any other pump problems and that fixing the shallow friction should return the card shape back to normal. Utilizing the surface card in this example may not be absolutely necessary, but it does give assurance that the diagnosis from the software is accurate.

CONCLUSION

When using sucker rod pumping as an artificial lift method for oil and gas wells, it's common practice for well analysts and production engineers to examine downhole dynamometer cards to diagnose equipment issues. While a majority of data used for diagnostics can be found in the downhole dynamometer card, this paper demonstrates that a more effective analysis can be done by also using the data and patterns found in the surface dynamometer card. Additional findings in this paper include:

- Dynamometer analysis must include data from both surface and downhole cards
- Analysis on downhole cards is still extremely valuable
- Improvements to downhole card calculations are possible
- Surface card analysis is also important
- New models are successful using surface card data to analyze pump and well conditions

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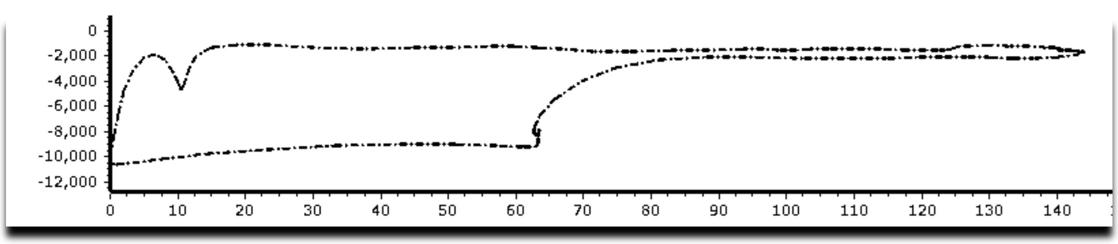

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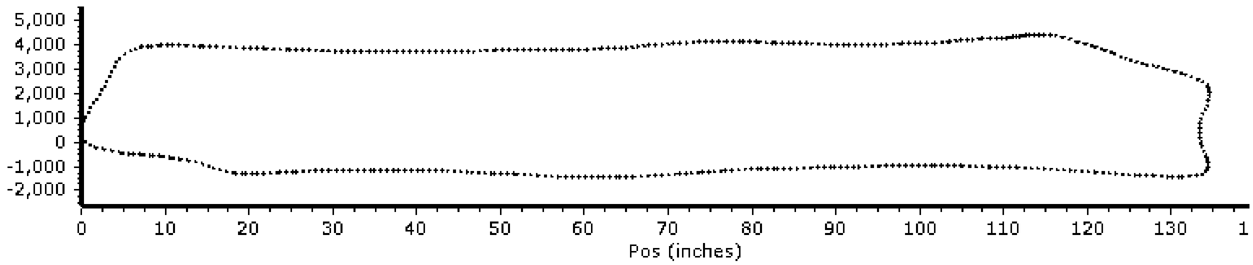

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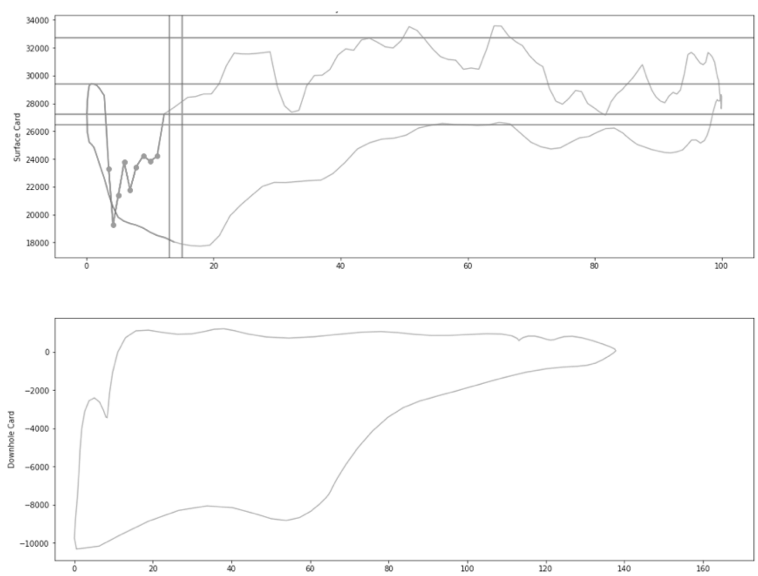

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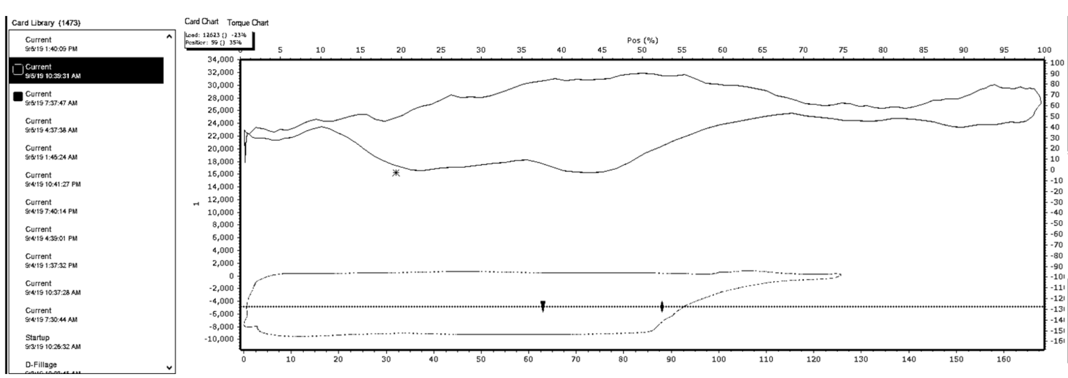

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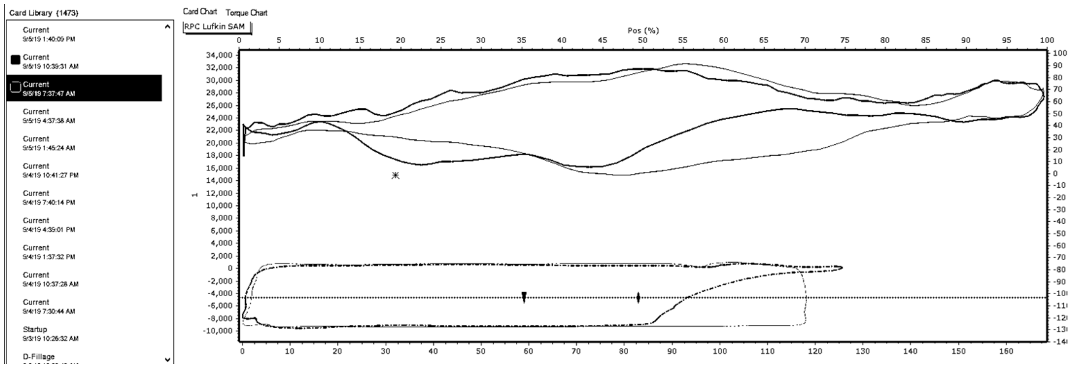

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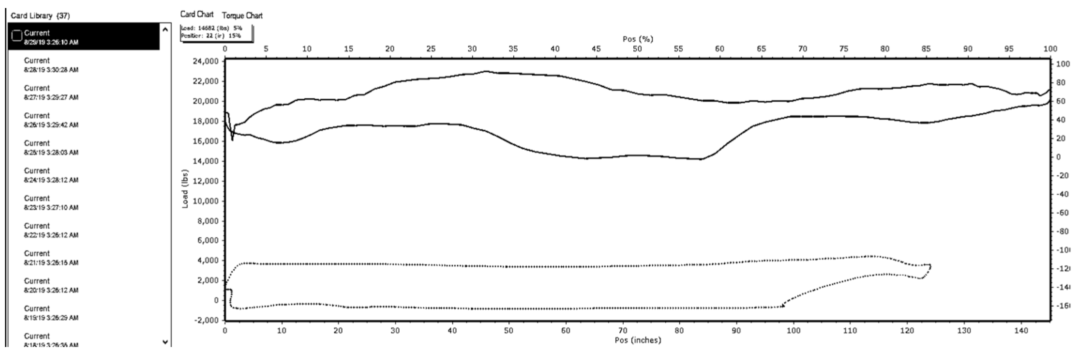

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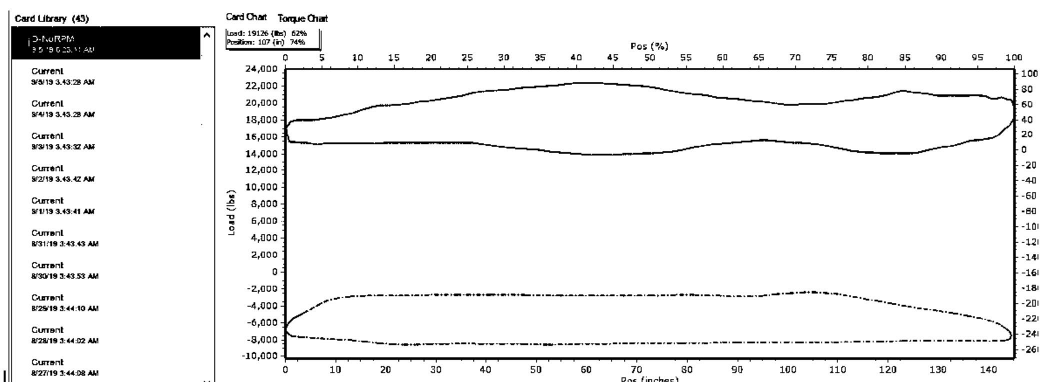

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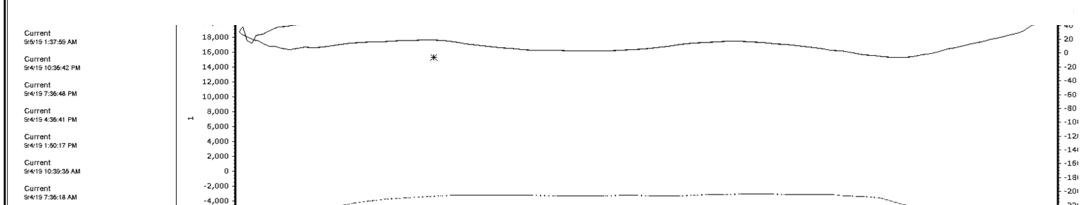

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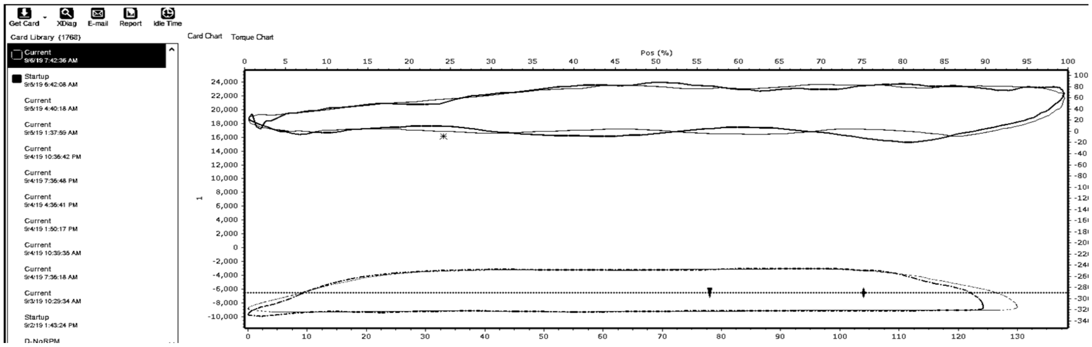

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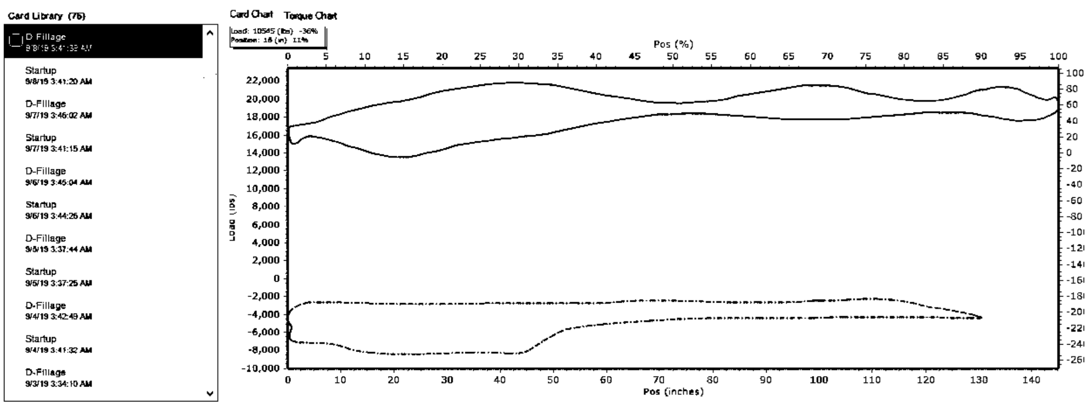

Figure 10

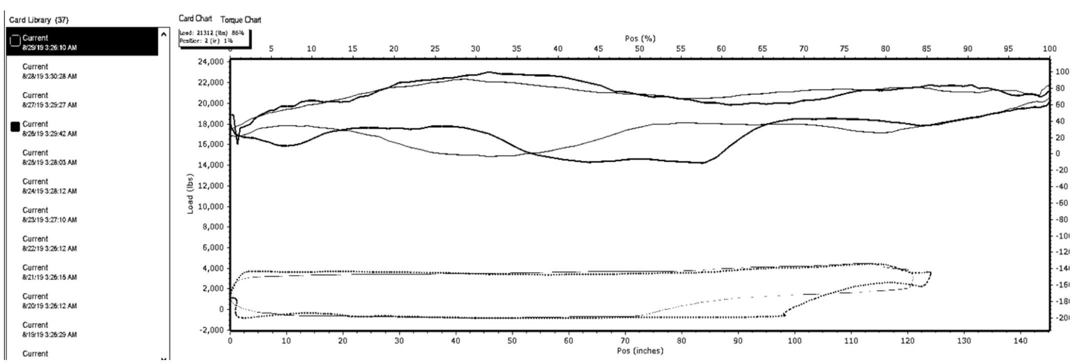

Figure 11