USING INTELLIGENT AUTOMATION TO AUTONOMOUSLY UPDATE SETPOINTS TO OPTIMIZE DYNAMIC WELL CONDITIONS FOR ROD LIFT WELLS

Ian Nickell

ChampionX

ABSTRACT

The ability to have host software autonomously optimize control artificially lifted oil and gas wells has obvious upsides for operators looking for productivity gains both for their workforce and their assets. In recent years, many strides have been made to develop such algorithms to allow operators to maximize performance on their artificially lifted assets. One of the most significant challenges that remains is how to optimize dynamic wells. Although there are many rules-based approaches that optimize based on certain conditions, it is important to recognize how dynamic many artificial lift wells are, especially unconventional wells. Fortunately, as our understanding of autonomous optimization and unconventional wells improves, algorithms and logic have been developed to allow the host software system to optimize wells based on the dynamic changes in the well bore.

After running autonomous control logic in the Bakken with a sample size of 40+ wells it is demonstrated that the logic updating setpoints such as idle time, pump fillage, and minimum pump strokes can be effectively optimized even with the well's operation dynamically changing. This is especially important in rod pump wells that are experiencing incomplete fillage due to gas interference as well as fluid pound. Although those conditions have similar characteristics, it is important to utilize different optimization techniques as a well fluctuates in and out of these conditions. Other dynamic conditions such as sudden increases in inflow and wearing equipment can also be optimized. This improvement in autonomous control technology has yielded significant benefits such as production increases where there is opportunity for uplift as well as improvement in pump fillage and decreasing the number of incomplete pump strokes daily, which can help reduce failures. This logic can be applied to a vast number of wells with different operating conditions and still autonomously make intelligent changes that dynamically improve operations as needed.

INTRODUCTION

For several years oil and gas operators have been using “controllers” to optimize their sucker rod pump artificially lifted wells. In terms of automation there are two separate strategies for onsite optimization, operators will either use a “pump off controller (POC) that is fixed speed, or utilize a controller with a variable frequency drive (VFD) which allows the controller to vary the speed to optimize the well. Although there are different manufacturers and the strategies for optimization do vary across controllers, the way fixed speed POCs and VFD controllers operate is quite consistent. Most devices control the wells based on the downhole dynamometer by using setpoints that the user configures to make sure the sucker rod pump artificial lift is meeting the capacity of the well, meaning that it is totally drawing the fluid level down, without running needlessly with incomplete fillage which will cause inefficiencies and is harmful to the artificial lift equipment.

Although this tried and tested method of operating wells is successful in several applications, when wells are experiencing really dynamic operating conditions the setpoints need to be changed almost daily or even more often. The issues is that most operators do not have time to dive into which wells are experiencing truly dynamic conditions let alone spend time analyzing the setpoints and making changes accordingly. Although many operators are capable of configuring the setpoints to optimize these wells, it is rare that these analysts and operators will have the time to spend changing all of these setpoints regularly.

STATEMENT OF THEORY AND DEFINITIONS

It is important to understand a few concepts. The first is the difference between fluid pound and gas interference. From expert to expert there may be some disagreement between definitions, but for the purposes of the analysis here, fluid pound will be defined as the condition in which the downhole pump is experiencing incomplete fillage because the artificial lift is producing all the fluid available and is now taking a low-pressure gas into the pump. For our purposes we will define gas interference as the condition in which the downhole pump is experiencing incomplete fillage due to reservoir gas being taken into the downhole pump even though there is still liquid above the pump for the pump to produce. Although these conditions are similar in their appearance and both cause inefficiencies, their impact on failures are different and the method of optimization for these conditions can be very different.

When a well is experiencing fluid pound as defined above, the well's production has been maximized and the optimal solution is to either idle or slow the equipment down depending on whether a VFD is present or not. However, in the case where a well is experiencing gas interference, there may be a disagreement among experts on the proper course of action. Research has shown that in many cases the gas in the pump chamber has higher pressure and does not cause the same harm on the downhole equipment as fluid pound does. Furthermore, it may be optimal to continue running the artificial lift equipment to make sure the well is producing as much as possible and not idling or slowing the well down because of the incomplete fillage because there is still production available.

Since there is such a drastic difference in optimization strategies between these two similar pump conditions, it is important for operators to differentiate between these two conditions and to configure these setpoints and control their wells accordingly. If this can be achieved, operators will be able to manage and optimize their wells so that their sucker rod pump systems maximize production without over pumping their wells and avoid increasing the risk of failures and/or decrease efficiency.

Lastly, there are several setpoints which can be used to optimize and manage the rod pump system. The primary setpoints for optimization depend largely on whether the rod pump system is being controlled by fixed speed pump off control or if a VFD is being utilized. For wells on fixed speed pump off control, the primary setpoints for optimization are the pump fillage and idle time setpoints. The pump fillage setpoint is the fillage threshold, as measured using the downhole dynamometer, that the rod pump system will go down on idle time when the measured fillage decreases below the value configured by the user. Essentially the pump fillage setpoint is the threshold that tells us whether the pump is “full enough” for the well to be operating. The idle time setpoint controls how long the well goes down when the pump fillage threshold is violated. These two setpoints are extremely important to the optimization of rod pump systems on fixed speed pump off control.

When a rod pump system is controlled using a VFD, the primary setpoints for optimization are the speed setpoints, which control how fast the well is going, as well as the fillage setpoints. Unlike fixed speed pump off control, a VFD can vary the speed of the unit so that the well does not need to idle. The speed of the unit is again controlled off pump fillage where the unit runs at the maximum speed while the pump is full and slows down when the fillage decreases. Most VFDs have the option to control based off two different pump fillage setpoints. These are called reference and secondary pump fillage. The VFD will begin to slow down when the fillage drops below the reference pump fillage setpoint, and if enabled the secondary pump fillage would tell the system to go down on idle time if the setpoint's threshold is violated.

DESCRIPTION OF APPLICATIONS AND PROCESSES

To optimize these setpoints for rod pump wells, especially wells that are dynamic and changing operating conditions, the first step is to perform analysis to understand whether the well is experiencing fluid pound or gas interference when the downhole pump fillage is incomplete. Most strategies for determining whether incomplete fillage is due to fluid pound or gas interference have used the shape of the downhole card. Primarily focusing on whether the change in load on the downstroke of the downhole dynamometer is abrupt or gradual. An abrupt change in load on the downstroke of an incomplete fillage downhole card indicates that the incomplete fillage is due to fluid pound. The abrupt load change is because the low-pressure gas that is present in the pump chamber does not increase the back pressure on the plunger as it moves through the empty pump. It is not until the plunger makes contact with the fluid that the pressure increases and the abrupt load change occurrs. When a rod pump system is experiencing gas interference the load change on the downstroke of the downhole dynamometer is usually much more gradual. This is because the presence of the higher-pressure gas in the pump chamber causes an increase in pressure as the plunger moves down the pump decreasing the volume. The pressure eventually increases enough to open the traveling valve and then the load decreases. Although this is a valid way of determining whether the downhole pump is experiencing gas interference or fluid pound, there are many times where it is not clear whether the load change is gradual enough to be considered gas interference. This is further exasperated by possible bad data that can cause the downhole card calculation to not have a card shape that is not perfectly representative of the loads that are occurring downhole.

To better differentiate between fluid pound and gas interference looking at the fluid load can also be extremely helpful. In cases where gas interference is present there is typically a level of gaseous fluid above the pump. This fluid causes a measurable amount of back pressure on the plunger during the upstroke while the standing valve is closed. Because of this the load on the downhole pump is less than expected. Although fluid load on it’s own is not a very reliable way to determine if there is gas interference or fluid pound, when combined with the strategy of analyzing the shape of the downhole card a more reliable diagnosis can be made to determine whether or not the well is experiencing gas interference or fluid pound.

Once the algorithms have determined whether there is fluid pound or gas interference, the autonomous control logic can be run with strategies specific to gas interference vs. fluid pound. In the case of fluid pound, the strategy is to ensure that the well is pumping off and thus maximizing production while looking to see if failures can be reduced, or even understand if production can be increased. In the case of gas interference, the strategy becomes to ensure that the rod pumping system is able to produce and even in some cases continue to pump through the gas interference despite the incomplete fillage.

When utilizing fixed speed pump off control, the strategy around the pump fillage setpoint is to ensure that the threshold is set higher for wells experiencing fluid pound. For wells experiencing gas interference the pump fillage setpoint can be decreased to pump the well more aggressively through the incomplete fillage due to gas interference. The values that the fillage are increased or decreased to are based specifically on the individual wells standard operating fillage and are focused on ensuring that the wells are going down on the pump fillage setpoint when the well is in fact experiencing fluid pound.

The other setpoint that is optimized is the idle time, and the algorithms optimizing idle time also depend on whether the rod pumping system is experiencing gas interference or fluid pound. In the case of fluid pound it is important to find the optimal idle time, which is simply the longest possible time for the well to be down without building up a fluid level in the casing anulus that decreases production. For wells with gas interference the optimal idle time philosophy is the same, however it is important to note that in some cases the optimal idle time one day will be drastically different the next day, so the algorithm must be more dynamic and not home in on one specific idle time.

These changes are made autonomously using a host software that iterates through different set points and then measures outputs like pump fillage, runtime, cycles, and inferred production to understand how the well has responded to the setpoint changes made by the host software. Although eventually the host software can find an optimum value for the pump fillage and idle time setpoints, it is extremely important to continue hunting and pursuing setpoint optimization due to the dynamic condition of the well.

Likewise, when a rod pump system is being controlled by a VFD the philosophy for both gas interference and fluid pound remain, as do the strategies for the host software autonomously optimizing the setpoints. However, when a well is controlled by a VFD, there are more setpoints that can be optimized to ensure the sucker rod pump system is matching the reservoir capacity. For a VFD well experiencing fluid pound, the algorithms primarily focus on keeping the fluid level at the pump while testing if there is an opportunity to decrease the operating speed of the well to reduce failures while maintaining production. In some cases where the rod pumping system is being controlled by a VFD and still idling due to incomplete pump fillage, the goal is decrease speed in a manner that allows the well to improve fillage before going down on idle time, enabling the rod pump system to run for 24 hours. With rod pumping systems experiencing gas interference the strategy remains the same except to configure the setpoints to continue to pump the well even more aggressively when a rod pumping system is experiencing incomplete fillage due to gas interference.

Algorithms were built and deployed on host software to understand the rod pumping system's operating condition as well as understanding whether the rod pumping system is being controlled by a VFD or fixed speed pump off control. With this analysis in mind, the host software's algorithms iteratively optimize and solve for the optimal setpoints for the individual rod pumping system based on it's unique characteristics and whether the well is experiencing gas interference or fluid pound.

PRESENTATION OF DATA AND RESULTS

The autonomous control algorithms have been deployed on several hundred wells, including a group of 40 wells with very dynamic operating conditions. During this trial the autonomous control logic was deployed primarily on wells with fixed speed pump off control with a few wells being controlled by VFDs. Prior to the trial the setpoints of the individual wells were all very similar whether the wells were experiencing fluid pound or gas interference. Additionally, even though the operators had a good pulse on the wells, it wasn't fully understood which of the wells were experiencing gas interference vs. fluid pound. Many of the wells had varying production rates and even demonstrated characteristics of both fluid pound and gas interference. Of the 40 wells, 32 of them had idle time increases, most of which were wells with fluid pound. The autonomous control algorithms we able to increase production on two gassy wells which were going down on idle time even though there was still fluid to pump in the casing. And six of the wells, including one on a VFD were able to increase fillage by either cycling fewer times or slowing the well down when there was no more fluid for the artificial lift to produce. The autonomous control logic was extremely effective at diagnosing which wells to optimize gas interference vs. fluid pound. In cases where there was fluid pound, the logic was primarily able to improve fillage, and reduce incomplete pump strokes on wells with fluid pound. When gas interference was detected, the logic was able to increase production. It is also important to point out that the wells the logic didn't decrease production on any of the assets, rather it reduced failures without decreasing production, or it increased production on wells that had available production.

In some cases during the trial the downhole conditions changed, in which case the autonomous control logic was able to detect and update the setpoints accordingly. In addition to the 40 well trial one other example of autonomous control logic updating setpoints in dynamic conditions is included as a case study to illustrate the capabilities of autonomous control especially when it is required to differentiate between fluid pound and gas interference.

Case study 1 – fluid pound with opportunity to improve fillage and cycle the well fewer times:

In the first example, the idle time increased from 45 minutes to 70 minutes, decreasing cycles from 20 to 12 cycles per day. The average pump fillage also increased by about 20%. The second example demonstrates the same improvements. In this case the idle time began at 30 minutes and increased to 64. This reduced cycles from 13 to 6 per day and improved average fillage by ~8%. These wells were determined to have fluid pound and by increasing the idle time, the wells cycled fewer times per day and the fillage increased. The improvements to these wells will result in fewer failures and all of this was achieved without reducing the production in either case. This is a prime example of wells experiencing fluid pound that the logic was able to detect and apply the proper algorithms to address this issue.

Case study 2 – fluid pound with changing reservoir characteristics

This case study demonstrates the autonomous control logic's ability to change setpoints when wellbore conditions change. Initial this well was determined to have fluid pound and there were opportunities to increase the idle time to reduce cycles. However, after several days the wellbore conditions changed and there was more fluid to produce. The algorithms detected this and immediately decreased the idle time to make sure that the rod pumping system can produce all the available fluids. It is important that the logic was able to autonomously detect this and configure the setpoints accordingly.

Case study 3 – decreasing pump fillage on gassy wells

In these two examples, the autonomous control logic determined that due to gas interference, there was an opportunity for a production increase. Since these were both on fixed speed pump off control the logic determined that the proper response was to reduce the pump fillage setpoint to 56% for example one and 57% for example two. For the first example there was an initial production increase of 20 bbls/day and then a sustained 10 bbls/day increase after steady state was reached. For the second example the production was increased by 8 bbls/day. In both examples the logic was able to respond to the gassy pump conditions and increase the production.

Case study 4 - VFD optimization for fluid pound well

In this example the autonomous control updated the VFD speed increase and speed decrease setpoints to make sure the rod pump systems changes speeds less drastically. Although the equipment was running 24 hours a day, the fillage was poor. In order to improve the pump fillage the logic autonomously reduced the rate at which the speed was changing which allowed the equipment to run at a more consistent and more optimal speed which improved the pump fillage and reduced the maximum speed that the rod pumping system runs at. This should help improve equipment reliability without hindering production.

Case study 5 - updating fillage setpoints for dynamic well

This case study is an excellent example of how the autonomous control logic can pivot the optimization when the wellbore conditions change. Initially the logic reacted to the setpoint being set too low and the well not cycling even though it was running with fluid pound 24 hours a day. The initial pump gillage change was an increase for 35% to 75% improved the pump fillage from an average of 73% to 90%. However, after a few days the wellbore conditions changed production increased with some intermittent gas slugging. In order to keep the well running 24 hours even when slugs of gas are momentarily passing through the pump the logic the decreased the pump fillage setpoint to 60%. Although initially the well needed to idle to improve the pump fillage without hindering production, that changed to needing to run 24 hours a day despite intermittent gas slugging.

CONCLUSION

Although there are challenges in determining the difference between fluid pound, it can be achieved using software. The autonomous control logic, in many cases was able to effectively determine the difference between fluid pound and gas interference and then apply logic to optimize the setpoints accordingly. The primary driver for optimization amongst fluid pound wells is to increase the idle time and reduce the cycles for fixed speed pump of control. For fluid pound wells on VFD the goal is typically to reduce failures by slowing the well down. When gas interference was detected, the logic primarily looked for opportunities for production increases. Instead of slowing the well down or idling the well the autonomous control looked for ways to continue pumping the well through the gas interference.

It is possible to control and optimize setpoints for wells even in dynamic operating conditions. This is an exciting advancement for autonomous control and can lead to a more robust production optimization strategy for operators, especially those with dynamic operating conditions.

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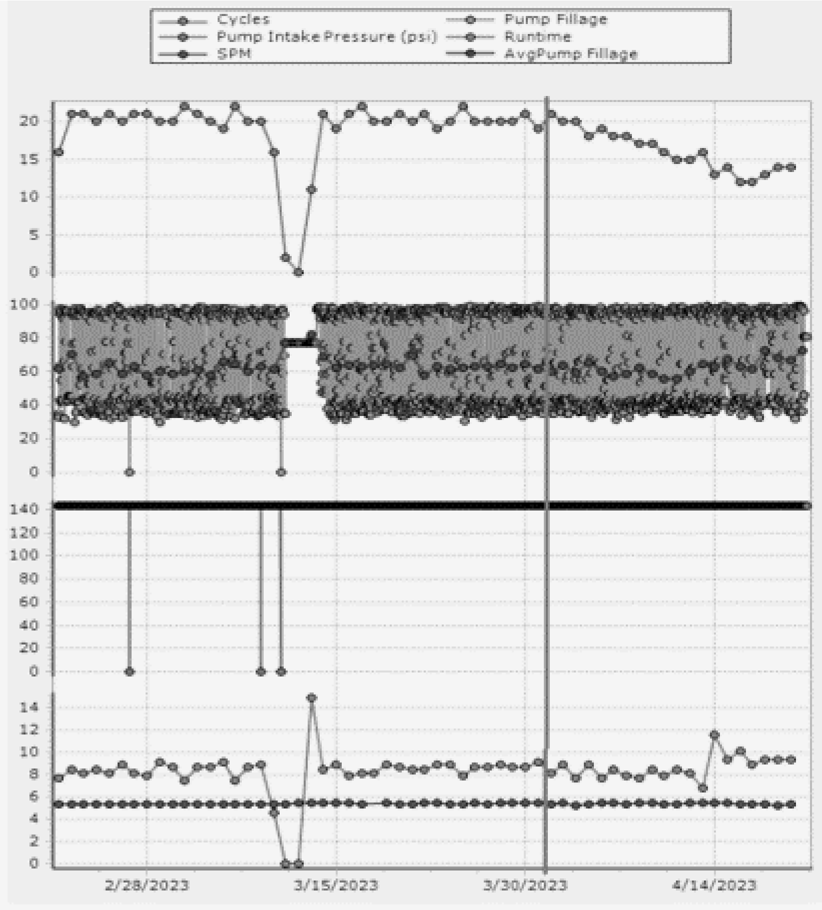
FIGURES

Case Study 1 Example 1



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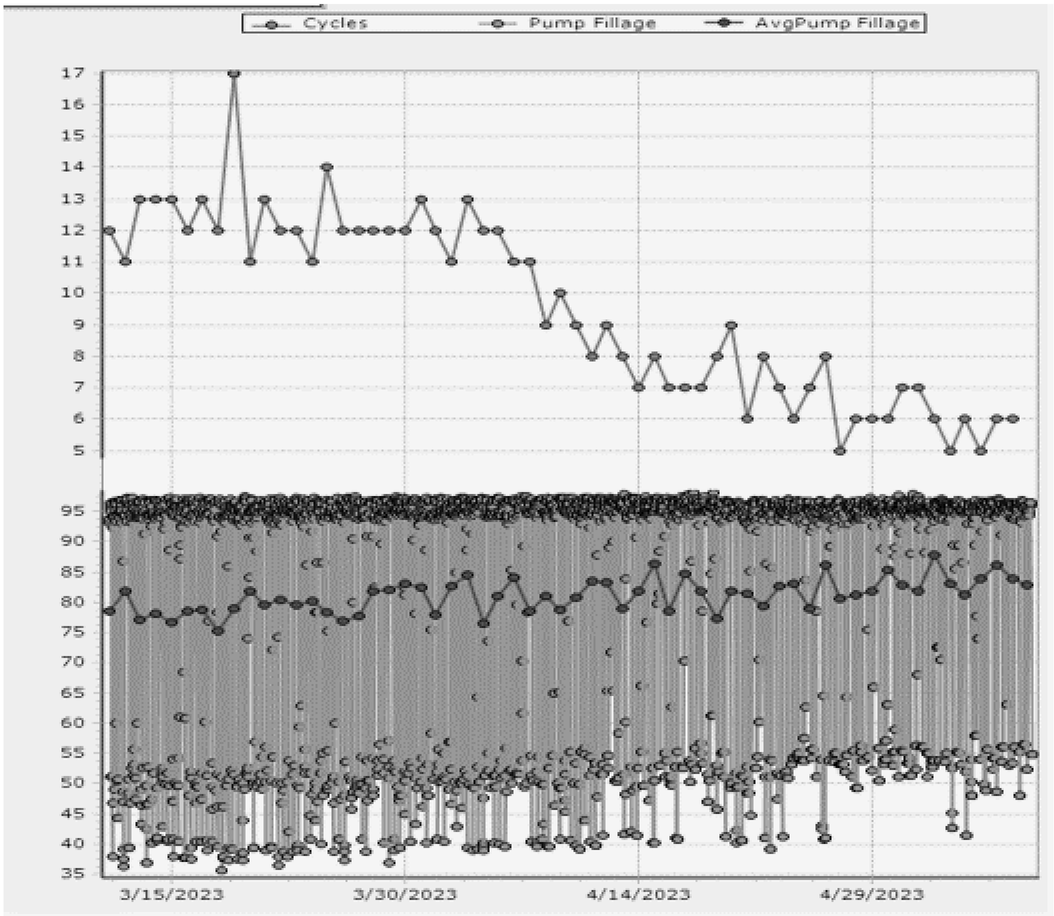
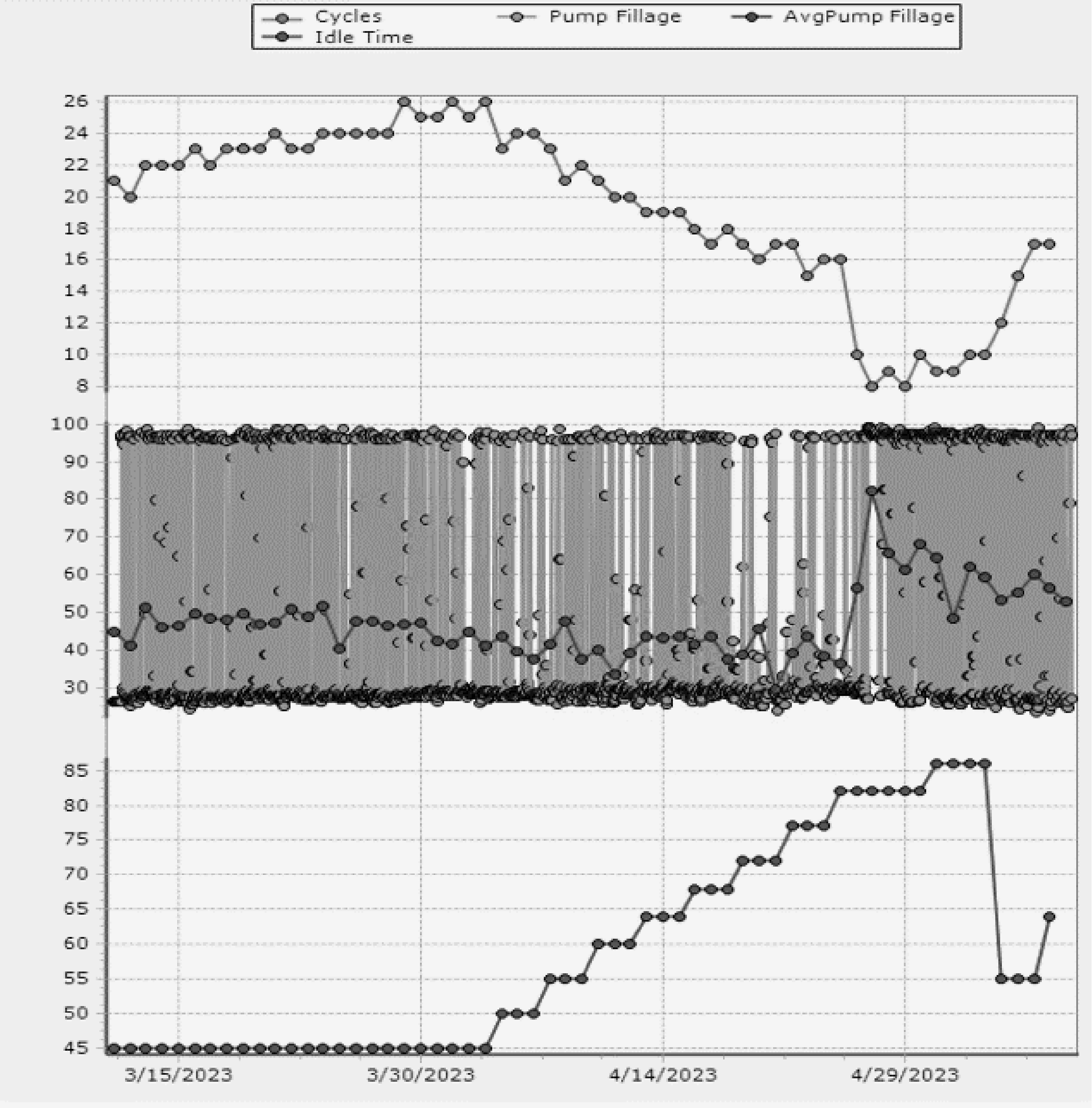


Case Study 2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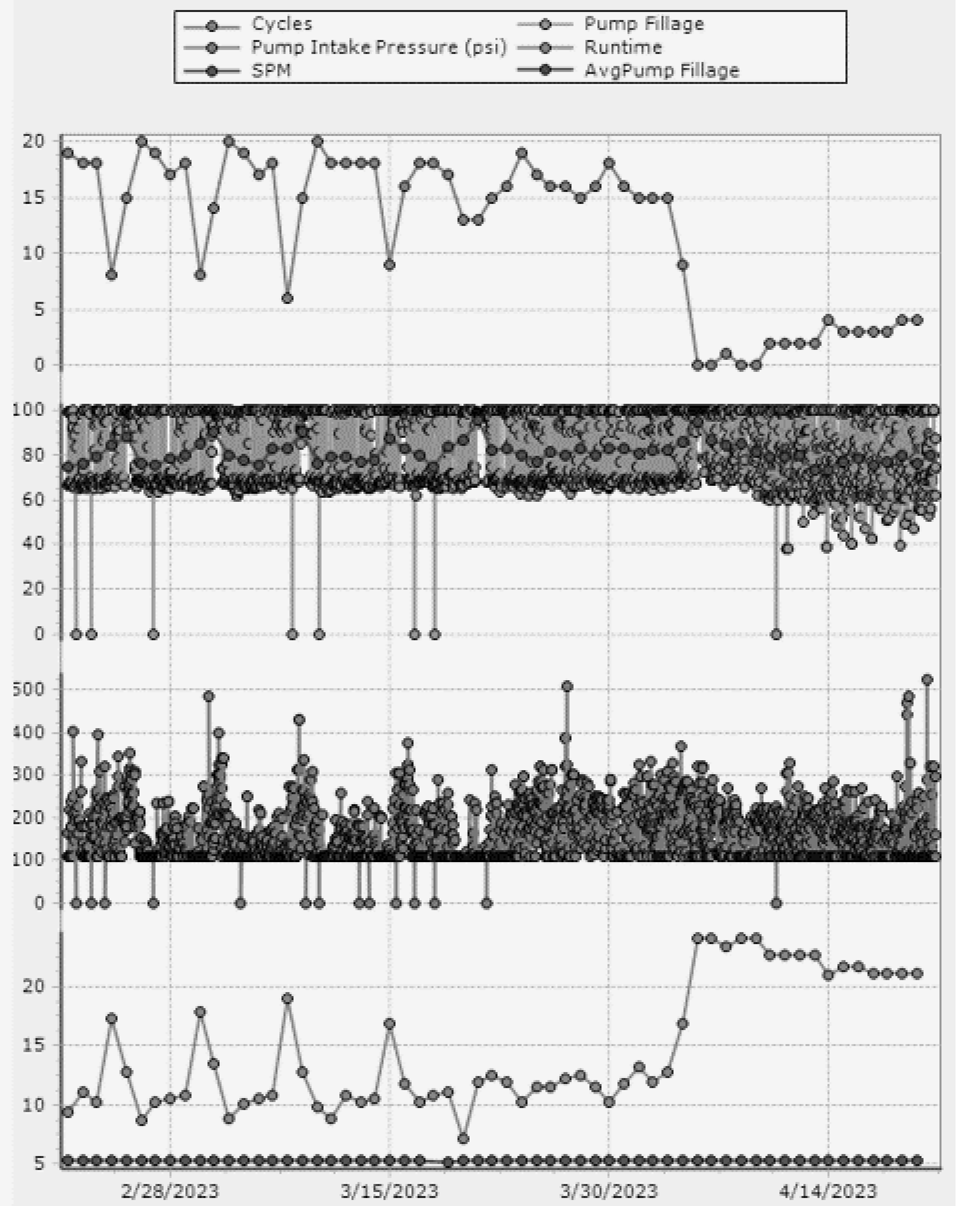
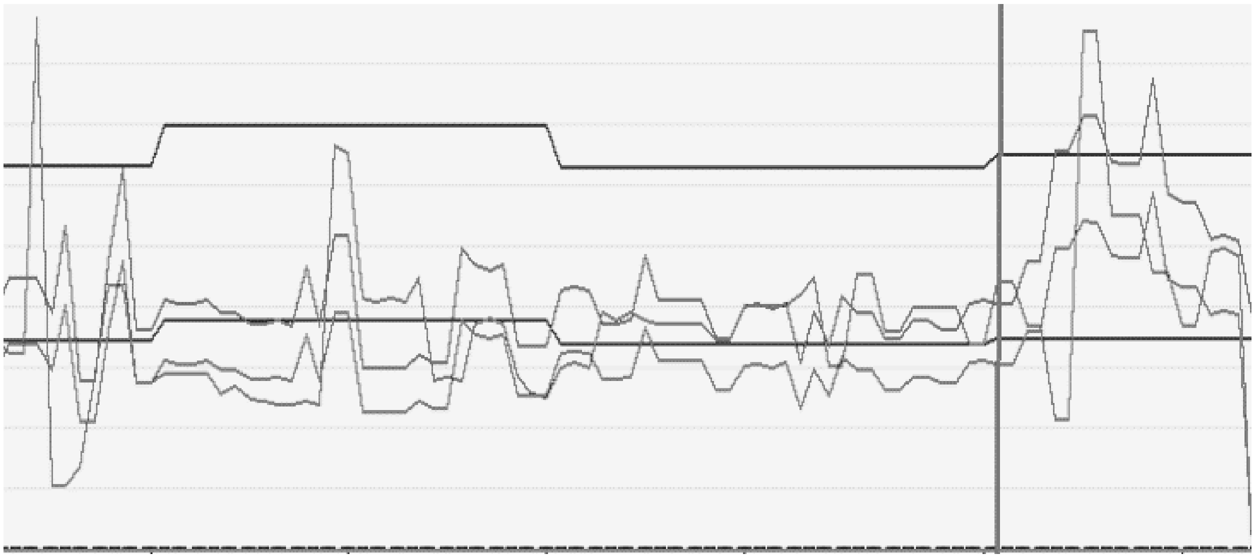
Case Study 3 Example 1





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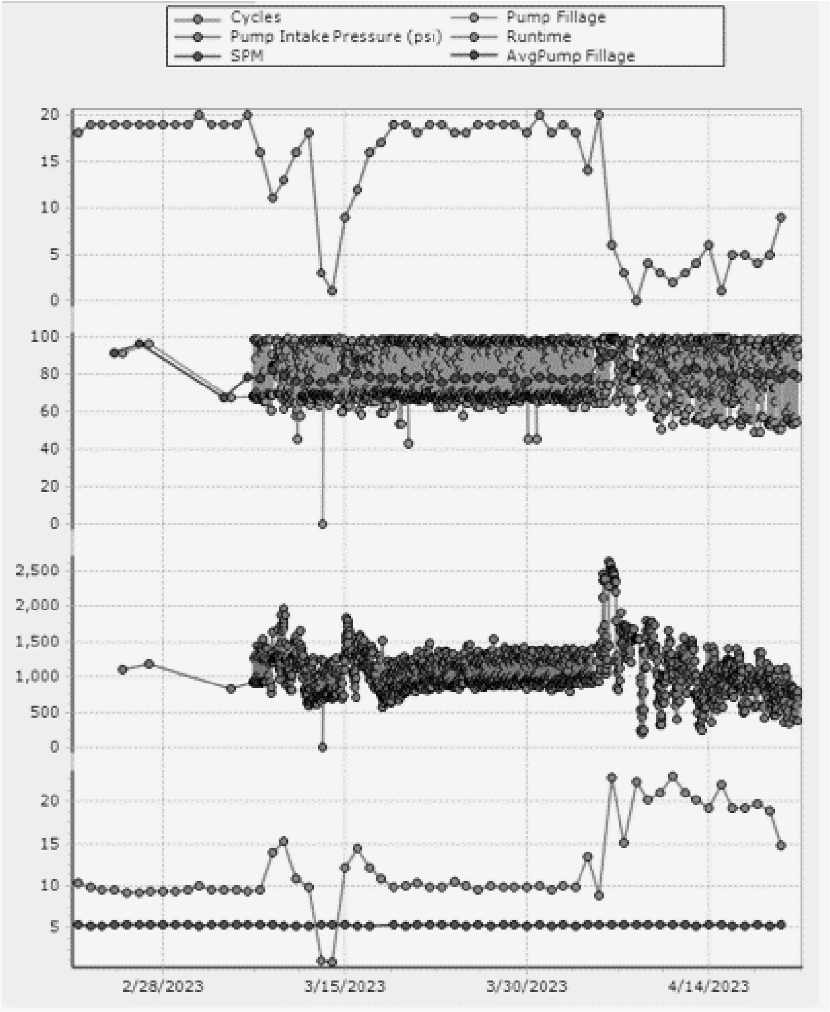

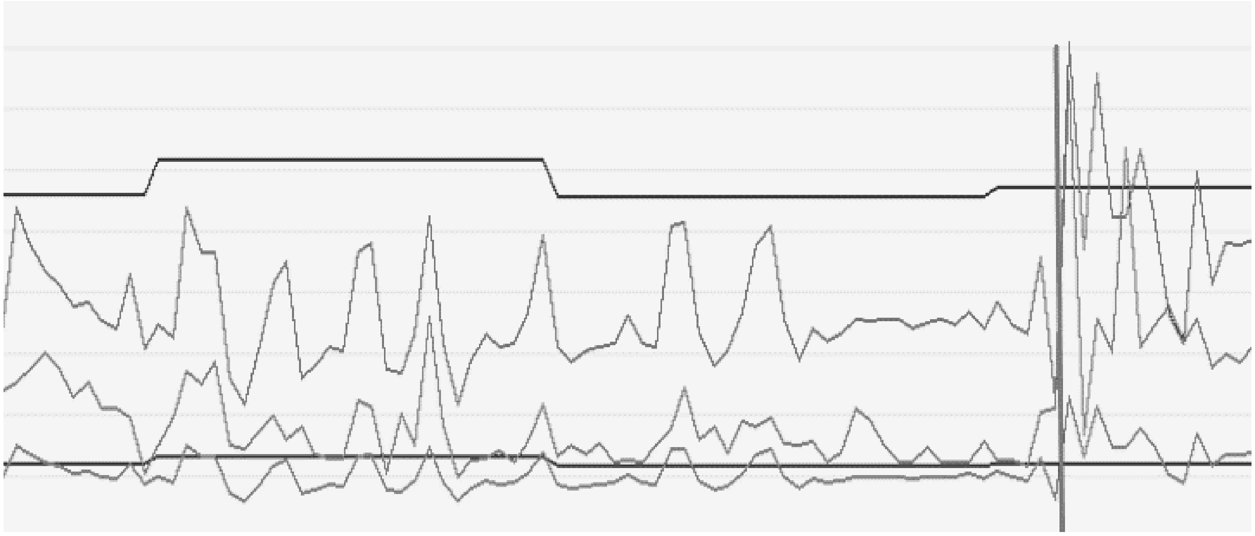

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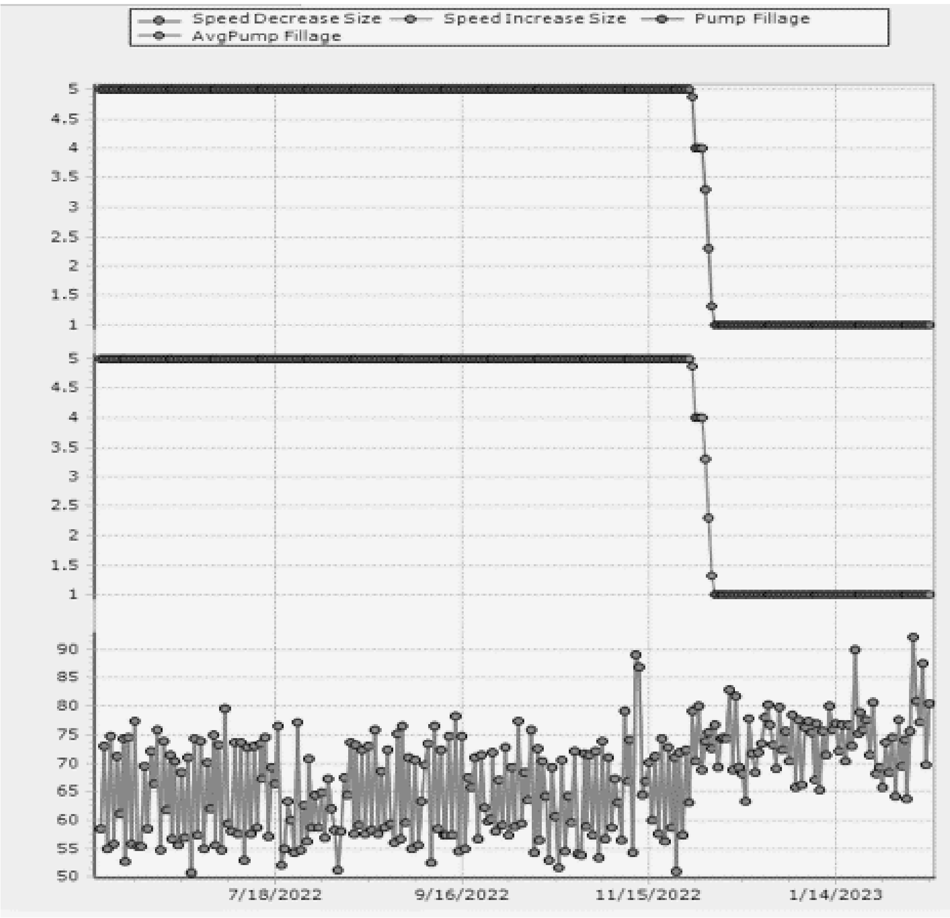

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Speed Increase Size
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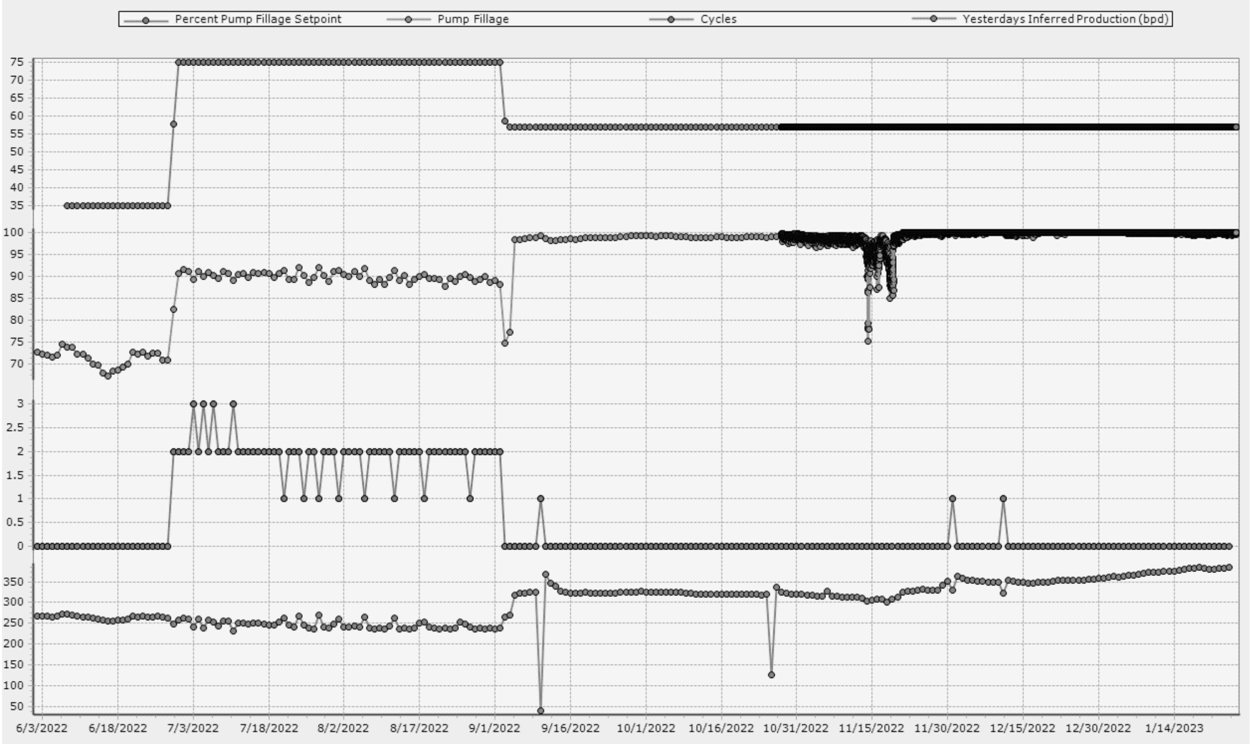
Case Study 5



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