Demonstrating unparalleled consistency through automation and objective visibility into drilling operations

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Abstract

Despite the great progress made in drilling operations over the past few decades the lack of consistency continues to be a well-known barrier to efficiency for the industry.

For many years the industry has invested heavily in training, standardization and performance management to drive operational improvement. Metrics are produced that break down the well construction process into a scheme, usually a list of activity codes to characterize the drilling operation with the goal of improving performance by identifying and managing sources of inefficiencies but not eliminating them.

Recent advances in technology and the steep increase in available computing power per dollar spent over the last 20 years is now allowing us to eliminate some of the root causes of inefficiency. The authors of this paper believe that human factors are the key to solving these challenges.

Introduction

This study aims to bring insight into the main sources of variance during the well construction process from the perspective of a drilling contractor. It shows the analysis carried out to identify the largest opportunity to reduce variance and discusses the implementation of a solution that involves automation.

Details and results of the recent experience gained by shifting the driller's role from performing repetitive tasks to supervising an automated system capable of generating objective sensor-based data are presented.

Stating the Problem

Well construction times have significantly decreased over the past decade. Figure (1) (Source: Rigdata: Well Location & Drilling Activities Queries)
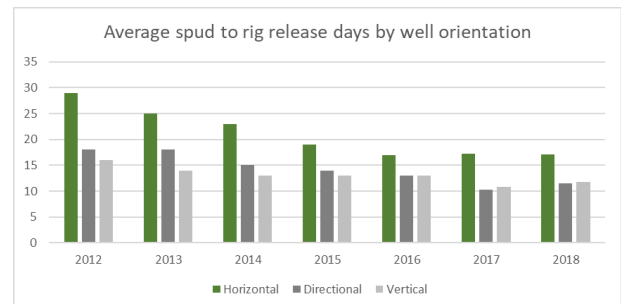

Figure 1 – Historical average for spud to rig release times in North America. Source: Rigdata: Well Location & Drilling Activities Queries

There are many reasons for this, such us additional hoisting, rotating and hydraulic power, more reliable and powerful downhole drilling and measurement equipment, optimized drilling mud systems and an increase in multi-well pad drilling. The list of reasons is by no means an exhaustive list, but it gives an idea of the many things that have contributed. However, despite the decreases observed in well construction times today a significant time variance can still be observed between the best and the worst times. Figure (2)
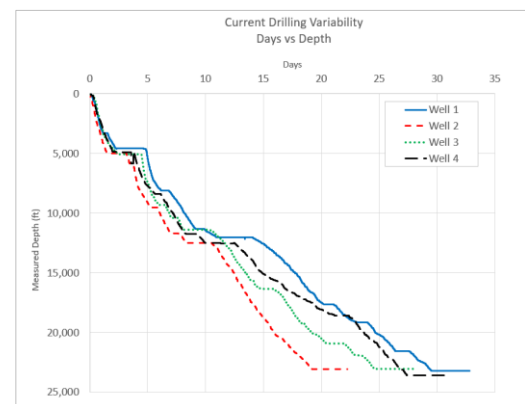

Figure (2) – Typical time variance observed today

The paper acknowledges that a percentage of the drilling time variance has an origin in the heterogeneous nature of the multiple formations that must be drilled in order to reach an oil & gas reservoir as well as the properties of the reservoir itself. Attempting to improve our understanding of this problem remains challenging. Although step changes in drilling efficiency have resulted in a significant reduction in on-bottom drilling times, we have observed that over the last decade the percentage of drilling versus non-drilling time has not decreased, in fact it shows a growing trend. —Figure (3)
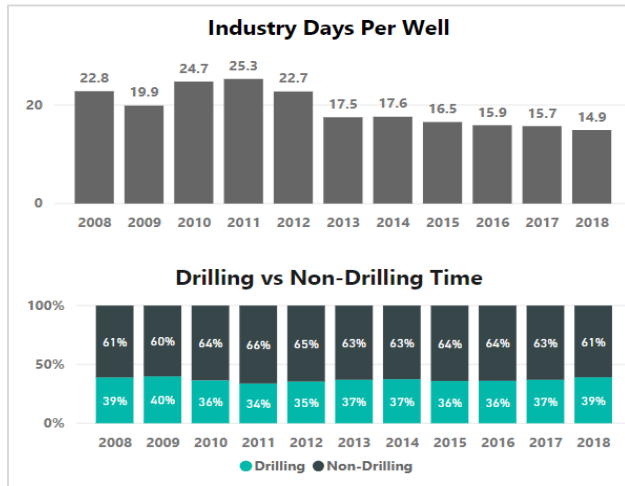

Figure 3 – Non-drilling times trend. Source: ETS from Precision U.S wells with Pason EDR

Non-drilling time remains a sizable opportunity target to reduce variance for a drilling contractor since many of the variables involved are within the contractor's control as opposed to the drilling piece. It is also worth mentioning that the current tendency to drill longer laterals tends to increase non-drilling times since more time can be spent conditioning the hole, reaming, surveying and tripping. In order to determine where to focus, non-drilling times during well construction were broken into major events and classified by frequency and overall time contribution.

At this point in time the scope of the analysis was narrowed down to a typical 18,000 to 20,000 ft horizontal well drilled, with Triple type rigs, in the busiest basin in North America, the Permian basin.

Non-drilling time events that occur only once during the well construction cycle were classified as low frequency, such as rig moves or rig walks. Events that happen multiple times within the well construction but rarely happen multiple times a day were classified as medium frequency, pipe trips and casing runs fall into this category. Events that happen multiple times in a day were classified as high frequency, drilling connections are part of this category.

The result of our analysis showed drilling connections to have a large variance in times within the medium to high frequency events and the biggest opportunity for improvement.

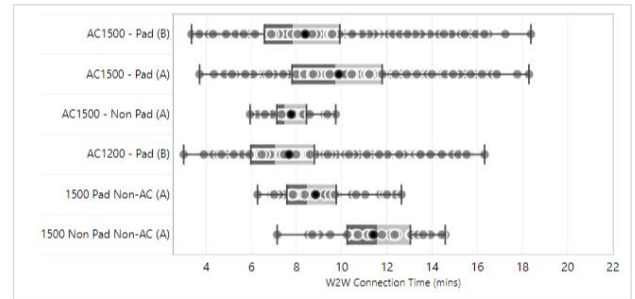Therefore, it was chosen as the area to focus. Figure (4 and 5)

Figure 4 – Weight to weight Variance in drilling connections by different triple rigs
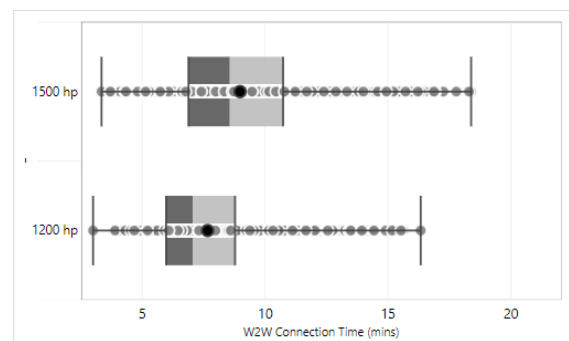

Figure 5 – Weight to Weight variance in Drilling connections by Horse Power.

Main causes of this variance

A drilling connection is composed of several activities that must be carried out in a specific order. These activities are executed primarily by the rig driller with the assistance of the rig crew.

The rig driller's primary duty is to operate the drilling and hoisting equipment via the driller's console but this is not his only responsibility. The driller is also responsible for the safety of the rig crew and performance all while operating two key pieces of well control equipment, the mud pumps and the blow out preventer. In addition, the driller is expected to optimize drilling and non-drilling times. This makes the rig driller the busiest person on location with multiple parties, the crew, the rig manager and the company representative competing for his attention.

Applying loss causation model techniques to the variance of times in drilling connections we came to the following conclusions.

Incident to analyze: High variability in drilling connection times.

Immediate causes:

Substandard Practices (people)
    Failure to follow quality procedures
        — Varied level of proficiency across drillers
        — Driller must respond to abnormal/unexpected well conditions
        — Driller's reaction time

    Failure to collect and analyze data
    Failure to identify and proceduralize statistical techniques
        — No objective way to capture process execution
Substandard Conditions (systems)
    Lack of resources (time)
        — Driller interact with multiple pieces of equipment during a connection
        — Driller multitasks while executing a process that is repetitive in nature

For everyone of these immediate causes several root causes have been identified.

Underlying /root causes

Substandard practices
    Failure to follow quality procedures
        Lack of skills
        Lack of experience
        Mental Distress

    Failure to collect and analyze data
        Lack of skills
        Lack of experience
        Mental Distress

    Failure to identify and proceduralize statistical techniques
        Lack of skills
        Lack of experience
        Mental Distress

Substandard Conditions (systems)
    Lack of resources (time)
        Inadequate process capability

Our approach to solve it

The analysis indicates similar underlying causes for substandard practices and conditions leading to time variances. These causes can all be addressed by reducing the number of repetitive tasks the driller executes when connecting pipe.

It is also critical to capture step by step process data that can be analyzed to optimize performance.

It was clear at this point in the analysis that the solution to this problem was automation, shifting the driller's role from a process executioner to a process supervisor, ready to engage in the event of a system failure or a sudden change in conditions for which the automated system may fail to respond adequately.

A parallel can be drawn with the role of the pilot in the aviation industry, (Reinhold and Close).

This paper focuses on multiple rigs over a period of 10 months where a process automation control system was deployed in order to address these underlying causes.

Operational steps that were automated

Operational steps are laid out (Farhangfar, Torre and Shor) in this section in order to identify and compare pre-PAC (Process Automation Control) and post-PAC datasets. Table (1)

Table 1 – Breakdown of PAC activities

PAC System Activity	Description
Slips to bottom sequence	
1. Add a Stand	Single/Stand added
2. Take weight	Lift string to pull slips
3. Ramp	Start circulation
4. Set rotation	Start rotating pipe
5. Tag bottom	Lower bit to start drilling
Bottoms to Slip Sequence	
1. Off bottom	Starts the process
2. Unweight bit	Drills off
3. Clear bit	Hoist a specific distance
4. Clean hole	Pump/rotate a certain period
5. Set box height	Hoist to connection position
6. Set weight	Sets ~~on~~ in Slips
Optional Activities outside the above sequences	
1. Reaming	
2. Surveying	
3. Friction testing	

To measure performance and utilization of the system a classification system was developed to indicate if the sequence was completed mostly by the (PAC) system, a combination of PAC and Driller, or by the Driller.

Since the process automation control system allows the driller to take control at any point in time interrupting an automated sequence the following classification of sequences was created.

PAC sequence:
Slip to bottom sequence = 4 out 5 activities are completed
Or
Bottoms to slip Sequence = 5 out of 6 activities completed.

Hybrid PAC sequence:
1 out of two possible sequences is at least a PAC sequence.

Driller sequence:
None of the sequences is a PAC sequence.

The percentage of PAC sequences completed out of the total possible sequences was established as a Key Performance Indicator (KPI) to measure effective usage of the system in conjunction with the following KPI's.
— Weight to Weight times.
— Bottom to Slips times.
— Slips to Slips times.
— Slips to Bottom times.

Our experience so far

As expected, a strong correlation was observed between complete uninterrupted PAC sequences and consistent times for connections. At the same time and in all those cases where the percentage of PAC sequences was higher than 70 %, a reduction in average and median values for weight to weight times across a well were observed. Figure (6)
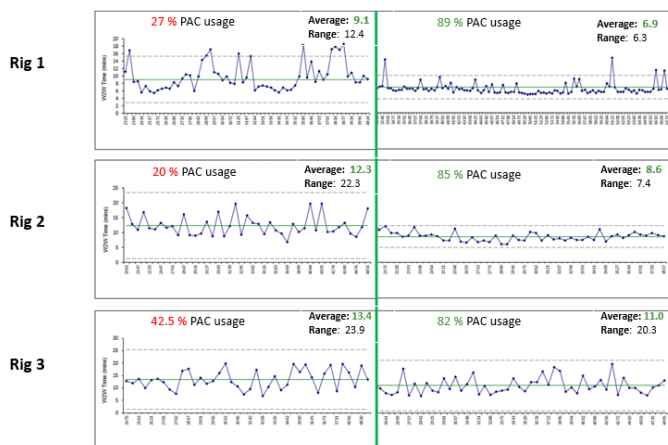

Figure 6 – Reduction in variance and average values using mean moving range control charts

What was not expected was the initial high level of sequence interruptions observed. To investigate this source of interruptions a detailed analysis was undertaken (Farhangfar, Torre and Shor) that led to the installation of data loggers in all rigs and the understanding that the driller must always be kept in the loop with a clear visualization of the current activity being executed by the Process Automation Control System.

An unintended consequence of the data logger systems was the benefit of having now SCADA type records of activities as opposed to inferred information from a system that was not designed to capture non-drilling activities. A common industry practice to measure connection times is to apply a certain logic to a combination of hole depth, bit depth, hook-load, pressure, torque and rpm measurements all of them originating from the Electronic Drilling Recorder (EDR) system. This logic needs to be constantly adjusted to fit different drilling conditions and or

sensor failures as well as constant field resetting and recalibrations making it very difficult to fully automate the process and achieve 100% accuracy.

The new process generates tags every time the process automation control system engages in an activity and the combination of this data with the EDR data allows full automation with 100% activity description accuracy.

This made possible to accurately segment a drilling connection in up to seven distinct sections,
1. Bottom to slips
2. Reaming
3. Friction testing
4. Slips to Slips
5. Surveying
6. Downlinking
7. Slips to Bottom

This additional granularity of operations allowed us to effectively identify sources of variance and put measures in place to reduce it.

Conclusions

In conclusion, let us summarize the major points in this paper.
- Automating activities around drilling connections with current process automation control technology leads to consistent connection times. Our experience shows that it can be as much as three times reduction in variance even if the system is engaged 70% of the time.
- As the consistency increases, the overall median and averages connection time decrease. Our experience shows that it can be as much as a 30% reduction.
- High level of utilization requires the driller to have full visibility and understanding of the current process step being executed.
- Process automation control generated activity tags can be combined with existing EDR data to produce accurate automated rig state detection which is critical to optimize performance.

Acknowledgments

Nomenclature

SCADA = Supervisory Control and Data Acquisition
PAC   = Process Automation Control
EDR   =Electronic Drilling Recorder
ETS   =Electronic Tour Sheet
HP   =Horse Power
AC1500 =1500 Horse Power AC Rig
AC1200 =1200 Horse Power AC Rig
W2W   =Weight to Weight times

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