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Tripping Optimization to Promote Flat Time Reduction in Oil and Gas Well Drilling Operations

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Abstract:
Tripping, relating to oil and gas drilling operations, is a term used to describe running in or pulling out tubulars into or from an already drilled borehole. It is common to all well delivery operations in the oil and gas industry, including drilling, completions, work-over, and abandonment.
Besides drilling a well that meets technical specifications in a safe manner and within the approved budget, well delivery success is not achieved if the specified time is exceeded. Time is an essential factor as it also has a large influence on cost. Well delivery time could be classified as either drilling time (time allotted to activities where the well depth increases with time) or flat time (time allotted to activities that do not directly contribute to an increase in well depth).
Flat time reduction is a key strategy used to reduce oil and gas well delivery cost. This is applicable in drilling operations, specifically where well cost is directly proportional to time. There is ample room for drilling performance improvement by reducing flat time without eroding well quality. Oil and gas well delivery performance engineers are, therefore, constantly seeking ways to reduce flat time to the barest minimum.
Tripping optimization refers to the application of specific methods aimed at preventing technical issues while tripping and reducing tripping time. Tripping is one of the major contributors to flat time, with typically circa 8 to 10% of planned tripping time (exclusive of casing and completion running time) in drilling operations. This means tripping optimization has a direct effect on flat time reduction and, by extension, well cost reduction.
This article discusses various tripping optimization techniques and how they promote flat time reduction in oil and gas well drilling operations. It emphasizes how drilling operations can be more time-efficient and consequently cost-efficient by improved tripping practices.

Keywords: *Tripping, tripping optimization, flat time, oil and gas well drilling, well delivery*

1. Introduction

Well delivery is a process that involves executing a well project safely to meet technical specification requirements within a specified time and budget.

Well drilling operations involve the process of creating a hole with a drill bit and a drill string, from the earth's surface to target zone(s), at some depth in the earth's subsurface. This process is usually done in stages; thus, wells typically have different hole sections. After every section, the hole must be secured, and this is usually done by running a casing string and cementing it in place. The casing string typically has a smaller diameter than the corresponding hole section. A typical land well has three hole sections:

- Top hole section (17.5-inch or 16-inch hole with a 13.375-inch casing),
- Intermediate hole section (12.25-inch hole with 9.625-inch casing), and
- Final hole section (8.5-inch hole with 7-inch casing or liner)

Some wells also have a 6-inch hole section and a 4.5-inch liner. In the offshore terrain, the hole sections are generally more. Prior to the 17.5-inch or 16-inch hole, there are typically two additional hole sections (36-inch and 26-inch hole sections). After the drilling phase, completion operations begin.

Flat time in oil and gas well drilling operations involves activities that do not increase the well depth. Simply put, flat time involves time used for all other activities apart from the actual drilling of the wellbore.

Tripping in oil and gas well delivery operations can be described as a well operations activity that involves either running tubulars into (*tripping in*) or pulling tubulars out (*tripping out*) of an existing borehole. Since tripping can only be done in a previously drilled hole and does not increase the well's depth, it contributes to flat time. An efficient performance improvement strategy is to isolate tripping operations and take deliberate steps during well planning for their optimization, with the aim of reducing flat time to the barest minimum.

2. Discussion

2.1. Typical Well Delivery Tripping Operations

Some examples of tripping in well delivery operations are:

- After drilling a hole section to the target depth, the drill string needs to be pulled out of hole (POOH) before the well is secured by running casing and cementing.
- After a previous hole section has been successfully drilled, secured with casing, cemented, and the next hole section needs to be drilled. Here, the drill string needs to be run in hole (RIH) to get to the top of a plug above the casing shoe track before drilling is resumed.
- RIH with a clean-out assembly for a wiper trip after an open hole section is left too long, without a pipe in the hole. There could be many reasons for this, but a classic is when a drilling program requires that open hole logging is done after a hole section is drilled, before the hole is secured by running casing and cementing. Typically, the drilling program should state a threshold time, which, if the open hole static time exceeds before completion of logging, a wiper trip needs to be done, to reduce the possibility of hole problems during casing running to the barest minimum.

Tripping, though considered routine (since it frequently occurs during well drilling operations), needs to be given detailed focus, as it could easily lead to well problems.

2.2. Well Problems which may be caused by Poor Tripping Practices

Poor tripping practices may lead to many well problems, which may be embedded in these two listed below:

- Loss of primary well control
- Stuck pipe

<u>2.2.1. Loss of Primary Well Control</u>

Well control involves deliberate activity by the drilling engineering team to ensure that hydrocarbons remain in-situ and do not flow to the surface during drilling operations. There are different types of well control: primary, secondary, and tertiary.

Primary well control is attained by maintaining a designed hydrostatic fluid level, which amounts to a higher pressure than the pressure in the fluid contained in the pore space of the interval that has been drilled into or drilled through. The difference in pressure is called overbalance and is also calculated. If the hydrostatic pressure due to the column of fluid above the reservoir reduces below the reservoir pressure, it is said that the overbalance is lost, and it is termed an underbalance situation. If the reservoir is self-flowing, it will result in a kick. On the other hand, if the hydrostatic pressure due to the column of fluid above the reservoir is much higher than the reservoir pressure, it is said that the overbalance is high. This is also an undesirable situation, as it may lead to the fracturing of some weak formations and, consequently, losses. Drilling fluid is used to achieve this hydrostatic pressure above the reservoir.

While POOH, if the drill string is pulled too fast, it may lead to swabbing the well and introducing hydrocarbon fluid into the borehole. If this process is not detected on time, and enough hydrocarbon to eliminate the trip margin is swabbed into the wellbore, it will result in a kick. Conversely, while RIH, surge pressures applied to the well may fracture the borehole and lead to losses. If enough drilling fluid is lost from the wellbore to result in an underbalance situation, it could result in a kick.

Kick or losses scenarios are unwanted in oil and gas well drilling operations, primarily because of the risk of uncontrolled flow of hydrocarbons to the surface. In addition, this increases flat time in well delivery.

<u>2.2.2. Stuck Pipe</u>

While RIH or POOH, a pipe could be limited in movement due to different mechanisms of downhole restriction. If this occurs, the pipe is said to be stuck. Time used to recover from a stuck pipe situation is regarded as flat time.

2.3. Tripping Optimization

Tripping optimization involves deliberate steps toward preventing technical issues and slow performance during tripping operations. The ultimate focus is to improve tripping performance and consequently reduce well delivery time and cost. These steps may be referred to as best practices for tripping, and they are highlighted below:

- Proper use of trip sheet.
- Maintaining safe trip speed.
- Reducing pipe stationary time to the barest minimum.
- Optimizing mud weight to reduce overbalance to the barest minimum.
- Optimizing trip speed.

<u>2.3.1. Proper Use of Trip Sheet</u>

2.3.1.1. What Is a Trip Sheet?

A trip sheet can be defined as a table that is used to measure the fluid level in the wellbore while tripping, to ascertain if there is a resultant gain or loss, or if the well is static. This is important for early detection of a well control situation and prevention from escalation, which may ultimately result in lost time and affect well delivery performance.

2.3.1.2. How Is a Trip Sheet Used during Tripping?

While POOH, the fluid level reduces as tubulars are removed from the wellbore. We need to add fluid to the wellbore to correct this reduction. While RIH, the fluid level increases as tubulars are added to the string in the wellbore. We need to remove some fluid from the wellbore to correct this increase. A trip tank is used for this addition or reduction of fluid from the wellbore.

While POOH, if the well takes more fluid from the trip tank than the calculated theoretical displacement of the length of tubular that has been pulled out, it means that some fluid has been lost, and the situation is termed 'losses'. On the other hand, if the well takes less fluid from the trip tank than the calculated theoretical displacement of the length of tubular that has been pulled out, it means that some fluid has been gained by the wellbore, and the situation is termed 'gain'. If the well takes the same amount of fluid as the length of the tubular that has been pulled out, the well is said to be static. This is what is expected in an ideal situation.

Let us consider a *tripping-out* operation (pulling dry) with the following specifications of tubular and trip tank.

- Trip tank height – 80 inches
- Trip tank volume – 40 barrels
- Trip tank capacity – 0.5 barrels/inch
- Drill pipe OD – 5 inches
- Drill pipe ID – 4.276 inches
- Drill pipe open-ended metal displacement capacity (Calculated) – 0.006524 barrels/ft
- Length of one stand – 95 ft

Sample Trip Sheet for Tripping Out								
No of stands RIH	**Length of pipe RIH (ft)**	**Trip tank level 1 (inches)**	**Trip tank level 2 (inches)**	**Theoretical Delta-TT Volume (bbls) -** ***Pipe length (ft) x capacity bbls/ft***	**Actual Delta-TT Volume (bbls) -** ***TT Level difference (inches) x TT capacity (bbls/inches)***	**Theor. DTT – Actual DTT Volumetric gain (+) / Loss (-) (bbls)**	**Cumulative Volumetric gain (+) / Loss (-) (bbls)**	**Remarks**
5	475	60	54	3.1	3.0	0.1	0.1	
10	950	54	48.2	3.1	2.9	0.2	0.3	
15	1425	48.2	42.6	3.1	2.8	0.3	0.6	
20	1900	42.6	37.2	3.1	2.7	0.4	1.0	
25	2375	37.2	32	3.1	2.6	0.5	1.5	

Table 1: Example Trip Sheet Record While POOH and Well Gaining

As seen from table 1, there is an increase in volumetric gain of approximately 0.1 barrels after every five stands POOH. This sums up to a cumulative volumetric gain of 1.5 barrels. It is a clear indication of a kick, and appropriate action needs to be taken to prevent escalation, which may increase the flat time.

While RIH, if the trip tank takes more fluid from the well than the calculated theoretical displacement of the length of tubular that has been run in the hole, it means that some fluid has been gained by the wellbore, and the situation is termed 'gain.' On the other hand, if the trip tank takes less fluid from the well than the calculated theoretical displacement of the length of tubular that has been RIH, it means that some fluid has been lost by the wellbore, and the situation is termed losses. If the well takes the same amount of fluid as the length of the tubular that has been RIH, the well is said to be static.

Let us consider a *tripping-in* operation (without a float valve in the string, i.e., string is self-filling) with the same specifications of tubular and trip tank as mentioned above.

As seen from table 2, there is an increase in volumetric loss of approximately 0.1 barrel after every five stands RIH. This sums up to a cumulative volumetric loss of 1.5 barrels after 25 stands are RIH. It is a clear indication of losses, and appropriate action needs to be taken to prevent escalation, which may increase the flat time.

A trip sheet usually has a remark column, as shown in both tables 1 and 2. Though this column has been left blank in these illustrations, it is useful for taking important notes that may affect tripping calculations. For instance, while POOH, the trip tank may need to be filled at intervals, and the volume added is recorded here. Conversely, while RIH, the trip tank volume may need to be reduced at intervals and the volume drained also needs to be recorded.

Losses or gains, if observed early, could prevent loss of primary well control, which could easily escalate to serious well control problems and reduce flat time.

Sample Trip Sheet for Tripping In								
No of stands RIH	**Length of pipe RIH (ft)**	**Trip tank level 1 (inches)**	**Trip tank level 2 (inches)**	**Theoretical Delta-TT Volume (bbls) -** ***Pipe length (ft) x capacity bbls/ft***	**Actual Delta-TT Volume (bbls) -** ***TT Level difference (inches) x TT capacity (bbls/inches)***	**Actual DTT – Theor. DTT Volumetric gain (+) / Loss (-) (bbls)**	**Cumulative Volumetric gain (+) / Loss (-) (bbls)**	**Remarks**
5	475	32	38	3.1	3.0	-0.1	-0.1	
10	950	38	43.7	3.1	2.9	-0.2	-0.3	
15	1425	43.7	49.3	3.1	2.8	-0.3	-0.6	
20	1900	49.3	54.7	3.1	2.7	-0.4	-1.0	
25	2375	54.7	59.9	3.1	2.6	-0.5	-1.5	

Table 2: Example Trip Sheet Record While RIH and Well Losing

2.3.2. Maintaining Safe Trip Speed

While RIH, it is important to maintain a safe trip speed, as if the tubular is run too fast, it could introduce surge pressures to the wellbore, a situation called surging. Surging could induce losses in the wellbore, leading to prolonged flat time and adversely affecting well cost.

While POOH, it is also necessary to maintain a safe speed, as pulling out too fast could also introduce swab pressures to the wellbore, a situation called swabbing. Swabbing a well could cause the well to go underbalance, especially if not detected early enough. This underbalance situation is called a kick and could easily escalate to a blow out if the well is not controlled promptly. Thus, pulling out too fast could ultimately lead to increased flat time and a worse scenario of losing the well and the rig. This may lead to poor well delivery performance and huge financial loss, potential loss of lives, and damage to the company's reputation.

2.3.3. Reducing Pipe Stationary Time to Barest Minimum

One of the mechanisms of stuck pipe is differential sticking, and this is prevalent while drilling or tripping through highly depleted reservoir sands. In such situations, the hydrostatic pressure needed to maintain a healthy overbalance between the wellbore and the formation sand is reasonably lower than normal. However, practically, the overbalance between the wellbore and the reservoir sand is usually higher than normal because there are typically other sands above or beneath, which are not highly depleted and require high mud weight to maintain well control. This makes the drill string in the wellbore exposed to high differential pressures and consequently more vulnerable to differential sticking. A major factor that enables differential sticking is contact time. If the contact time is reduced to the barest minimum, it reduces the friction between the tubular and the wellbore and reduces the possibility of getting differentially stuck.

Prior to tripping operations with a potential risk of differential sticking, this risk should be highlighted accordingly, and the appropriate mitigation addressed – reducing stationary time to ALARP.

2.3.4. Optimizing Mud Weight to Reduce Overbalance to the Barest Minimum

While tripping, especially in formations with a high risk of differential sticking, it is important to ensure that mud weight is maintained such that the overbalance does not exceed what is required. In the scenario of tripping through severely depleted sands, with higher pressured zones either above or below, in the same hole section, it is important to ensure that the mud weight requirement is met but not over-designed, as this increases the differential pressure between the wellbore and the formation and makes the drill string prone to differential sticking. These measures could be implemented by:

- Studying the drilling program carefully and checking for reservoir pressure and mud weight requirements, which gives the minimum overbalance required.
- Ensuring the on-site mud engineer has a good grasp of the drilling program, the peculiarity of the situation, and what is required.
- Supervising the calibration of the on-site mud balance (used for measuring drilling fluid weight) using a fluid of known density, usually fresh water.
- Ensuring that the weight of the drilling fluid in the borehole is checked prior to tripping out of the hole and reducing overbalance to a safe value (within program specification) if necessary.

These actions help in the prevention of differential sticking and ultimately contribute to better well performance time.

2.3.5. Well Performance by Optimizing Trip Speed

One of the ways to optimize well delivery time is by efficient tripping. Tripping operations should be done in the least time possible without compromising tripping best practices. One of the ways to measure tripping performance is trip speed.

Trip speed is a measure of the length of tubulars RIH or POOH in a specific time interval, and this is usually expressed in joints per hour or stands per hour. A joint of drill pipe is approximately 31.5ft, and a stand of drill pipe (on a three-joint per stand rig) is approximately 95ft. Tripping inside the casing is usually faster than in an open hole because the possibility of meeting restrictions in the casing is much lower. During pre-execution events, tripping time is set based on minimum trip speed, and this must be adhered to during operations to increase the chance of meeting well delivery time target.

Trip speed is calculated by any of the following methods:

- Counting the number of drill pipes RIH or POOH and dividing it by the number of hours within the specified time interval. For instance, if 54 joints of drill pipe are RIH in three hours, Trip speed = 54/3 = 18 joints per hour, or, Trip speed = 6 stands per hour (Where 1 stand = 3 joints of drill pipe)
- Calculating the actual length of pipe RIH or POOH in the specified time interval and dividing it by 31.5 to get the number of joints that made up that length. Afterward, divide the number of joints by the number of hours within the specified time. For instance, if we make a depth progress of 1701ft while RIH within a time interval of three hours, Number of joints = 1701 / 31.5 = 54 joints. Trip speed can then be calculated in stands per hour, as above.

During well execution, trip speed is calculated while tripping and used to measure the actual versus plan. This performance monitoring strategy contributes greatly to flat time reduction.

3. Recommendations

- During oil and gas well delivery planning for drilling highly depleted reservoir sands, adequate borehole stability analysis should be done to ascertain the optimum mud weight to reduce the probability of differential sticking.
- In well delivery performance planning, challenging and SMART KPIs should be set for tripping operations, and this should be an input to the planned well delivery time in the drilling program.
- There should be an up-to-date repository of trip sheets for all types of tubulars to be used on the rig, during drilling operations. Drilling supervisors should be trained to apply the appropriate trip sheet.
- The drilling program should contain clear instructions to mitigate swabbing or surging the well during tripping out and tripping in, respectively. This should be adhered to by the drilling supervisor, by replicating the same in his/her work instructions.
- Actual trip time should be compared to planned trip time, real-time while tripping, and necessary adjustments should be made.

4. Conclusion

Tripping operations can be optimized to reduce flat time to the barest minimum in oil and gas well drilling operations. Typical tripping operations are POOH after a hole section is drilled, RIH with a new BHA to drill the next hole section, and a wiper trip after an open hole section is left idle past an acceptable threshold. Some problems that may be associated with poor tripping practices are loss of primary well control and stuck pipe. These could be mitigated by applying some outlined best practices for tripping:

- Proper use of the trip sheet,
- Maintaining safe tripping speed,
- Reducing tubular stationary time to ALARP, and
- Optimizing mud weight to ensure that overbalance is as close as possible to the program specification.

In the absence of technical issues while drilling, tripping operations may also be unusually slow, and this can be optimized by setting tripping KPIs, one of which is trip speed, and monitoring it during operations. All these actions contribute to reducing flat time due to tripping and ultimately reduce well delivery time and cost performance.

5. Abbreviations

- ALARP – As Low as Reasonably Practicable
- BHA – Bottom Hole Assembly
- KPI – Key Performance Indicator
- POOH – Pull Out of Hole
- RIH – Run in Hole
- SMART – Specific, Measurable, Actionable, Realistic and Time-bound
- TT – Trip tank

6. References

i. *Shell Wells Distance Learning Package V 2.0.0 - Well Control Principles and Practice*
ii. *SPDC Drilling Engineering Procedures Manual - Well Control and Pressure Prediction (Chapter 12)*