

SEEING THROUGH SOFTWARE



Pegasus Vertex, Inc.
Drilling Software

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GEFEI LIU AND CISSY ZHAO, PEGASUS VERTEX INC., USA, EXPLAIN HOW THE USE OF ADVANCED SOFTWARE CAN HELP ENGINEERS 'SEE' UNDERGROUND BY PREDICTING SUBSURFACE CONDITIONS.



Oil well drilling is one of the most fascinating engineering collaborations, with drill bits, tubulars, motors, mud and many other components all playing a part. Most impressively, all the drilling processes take place under the ground, probably tens of thousands of feet, maybe even horizontally, away from the rig.

To keep drilling operations under control, many technologies have been developed that incorporate electronic, magnetic and radiation-based methods in order to understand the formation and downhole conditions.

The rig floor is in some ways similar to a giant floating iceberg, with only 10% of its volume above the water. Drillers have some limited information, which includes hook load, surface torque, etc. However, they do not know the axial force along the string, whether the pipe is buckled, or if the torque on pipe connections exceeds the makeup limit. Experienced drillers may be able to sense downhole problems through the combination of brake vibration, noise or pump pressure, etc. But what is needed is something to bridge the gap between what can and cannot be seen. Drilling software serves as this bridge!

Over the past 20 years, drilling engineering software has become an indispensable engineering tool in the design phase, real time monitoring and post job analysis. Using known operation parameters

such as ROP, RMP, mud weight, drilling string configuration and well path trajectory, modern software can predict pipe buckling, hook load, surface torque and casing wear accumulated in the previous set casing.

For drilling engineers, software is beginning to act as another set of eyes. Equipped with software, it is possible to not only understand what can be seen (why there is a certain hook load, surface torque, etc.), but it is also possible to see events that would have otherwise been invisible.

Torque and drag

Drilling engineers use torque and drag software mainly for three reasons:

- ▶ Design operation.
- ▶ Onsite job monitoring.
- ▶ Post-job analysis.

No matter what is on a user's mind, they all want to trouble-shoot potential problems with ease.

The easiest way of presenting information is to use graphs. Whatever can be expressed in numbers may be expressed by charts, or in many cases, by 3D visualisation. This is especially true for drilling professionals as the operation occurs downhole.

Drillpipe buckling, tension and torsional failures (shown in Figure 1) are among many concerns within the drilling section. This educational graph is an

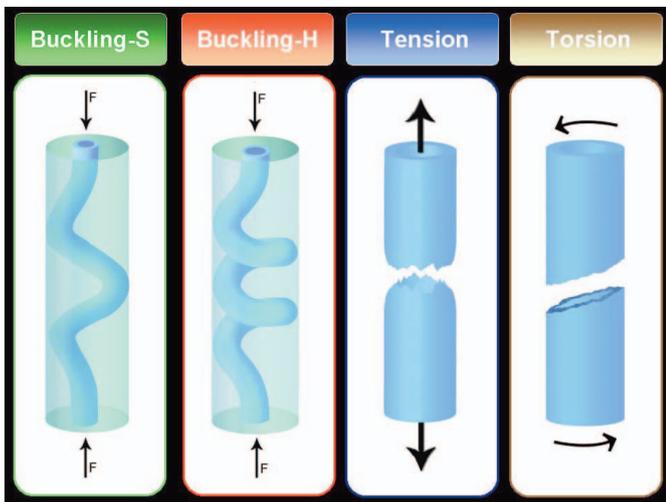


Figure 1. Drilling problems.

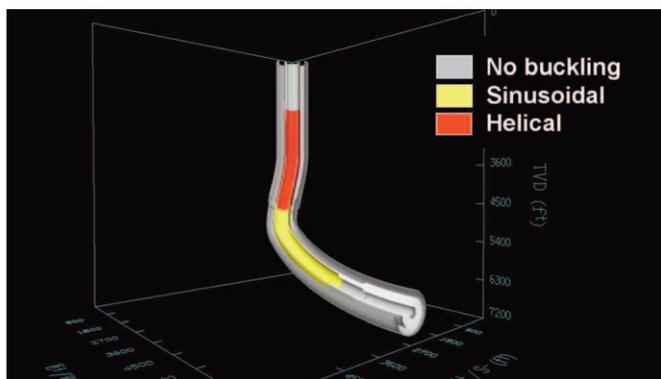


Figure 2. Buckling.

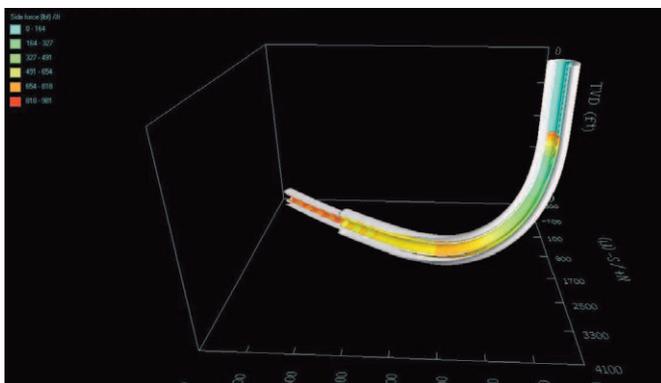


Figure 3. Side force for a directional well.

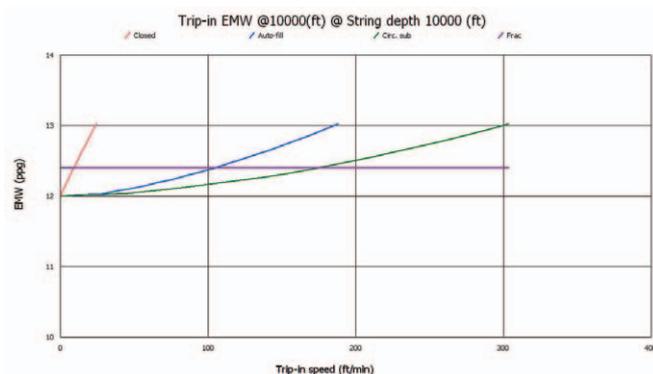


Figure 4. Surge pressure prediction.

artistic way of showing potential problems. In daily life and work, one faces numbers and tables; one of the most effective ways to describe, explore and gain insight into the numbers is to picture them.

Drilling software has come to play an important role in bridging the gap between illustration and reality. For example, the buckled sections of a drill string can be best explained in Figure 2 where the red colour stands for the helically buckled section, while the yellow represents sinusoidal buckling.

The side force is closely related to the well trajectory including dogleg severity. Figure 3 demonstrates a side force distribution along the pipe. This is also the source of casing wear to be discussed later in this article.

Casing running and surge pressure

New drilling and completion technologies such as horizontal wells, extended reach drilling, slim holes, deepwater offshore drilling, etc., have a tremendous economic impact in our industry, but also challenge many aspects of drilling and completion operations.

For example, surge and swab pressures are normally high because of restricted flow paths and a limited number of casings and liners. Running liners in subsea casing strings with very tight tolerance can cause extremely high surge pressures. Closed end float shoes are almost impossible to run in cases such as these without causing a loss of circulation. Auto-fill float equipment and other new tools such as flow diverters have been developed to reduce the surge pressure against formation. However, engineers are still facing the same challenges of determining the surge and swab pressure for these wells using new technology.

The accurate prediction of surge and swab pressures is of great importance in wells where pressure must be maintained within narrow limits to ensure trouble-free drilling and completion operations.

One way to see the impacts of various operation parameters is by using a sensitivity study. Figure 4 shows the surge pressure for various running speeds. It provides allowable tripping speed to avoid formation breakdown.

Cementing job simulation

A successful cementing job is one of the most important factors in the productive life of any well. Many software packages simulate the effects of various design parameters, and identify and correct potential problems before a job is actually performed. These models normally address a wide range of concerns, including free-fall, ECD and pump pressure requirements, and displacement efficiency.

Centraliser placement

A centraliser is a mechanical device used to position casing concentrically in the wellbore in order to provide a constant annular space around the casing. Proper placement of casing centralisers is one of the most important factors in obtaining a good primary cement job.

Engineers' concerns are: can we achieve the required standoff? Are we using too many unnecessary centralisers? Do we get any benefits from the placement of centralisers during the casing running?

Centraliser placement software helps determine the optimum number and placement of centralisers, and calculates the minimum casing standoff for both bow spring and rigid

body types. The software not only models the engineering behind the casing sagging in a directional well and how wellbore trajectories, cementing slurry density, pipe weight, etc., impact the placement of centralisers, but also models how the presence of centralisers impact torque and drag when running the casing.

This kind of modelling is essential for operators and service companies to achieve their engineering goals with optimal costs and a good cementing job.

Tubing movement

Most wells are completed and treated through a system of tubing and packers. Changes in temperature and pressure inside or outside the tubing will either cause a tubing length change (free motion condition) or induce forces in the tubing and on the packer (limited motion or anchored condition).

In shallow wells where there is a significant amount of overpull available in tubing and where extreme pressure and temperature variations are not likely to occur, we normally can rely on past experience or general rules of thumb to avoid trouble; however, in deep wells, conditions become more critical and tubing and packer failures are more common.

Typical tubing movement software performs the length change, force distribution calculation and checks the tubing integrity for various conditions; the purpose of this is to provide the industry with easy-to-use tools to avoid tubing/packer failures.

Casing wear prediction

In the drilling phase, casing is the most costly part. On top of expensive casing material and costs likely to be encountered in cutting, pulling and replacing a worn or damaged string, casing wear creates more serious problems for operators due to its potential for catastrophic incidents such as oil spills, blow outs or the loss of a well.

Casing wear is caused by drillpipe movement inside the cased hole, especially the tool joint rotation against the casing interior. Since no truly vertical well exists (the whirring action of the bit always creates a micro-helical shape of well path), contact between drillpipe and its tool joint with casing ID is unavoidable.

The gravitational force acting on the drillpipe will always try to pull the pipe to the lower side of the wellbore, while the axial tension on the drillpipe, in a build-up section, pushes the pipe to touch the upper side of the wellbore.

Depending on the pipe weight, dogleg severity and axial force along the pipe, the drillpipe either touches the upper or lower side of the wellbore. Modelling can determine the direction and magnitude of side force on the wellbore. In this way, one can know if the drillpipe is touching the upper or lower side of the cased hole.

Under this side force, the tool joint of drillpipe is rotating against the casing inside, gradually removing steel from the casing wall and forming a crescent-shaped wear on the casing, as shown in Figure 9.

The first step of predicting casing wear is to study the torque and drag along the drill pipe during drilling operations. From the torque and drag analysis, side force can be determined. For every incremental drilling interval, the amount of energy transferred from drillpipe to casing is calculated through a coefficient called wear factor. Accumulative wear and wear depth are obtained. Then the burst and collapse strength of the worn casing can be assessed.

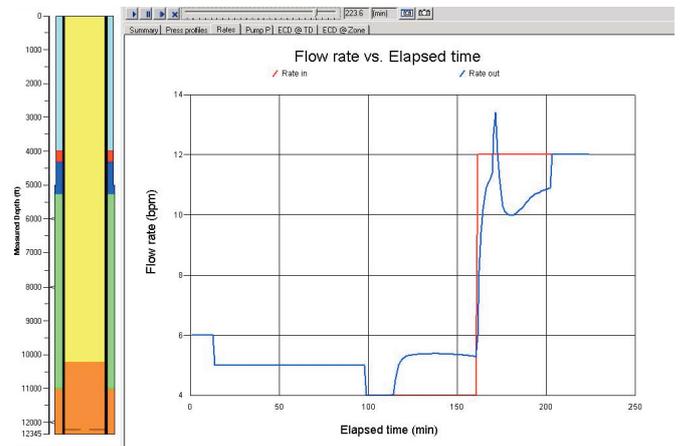


Figure 5. Cementing job simulation.

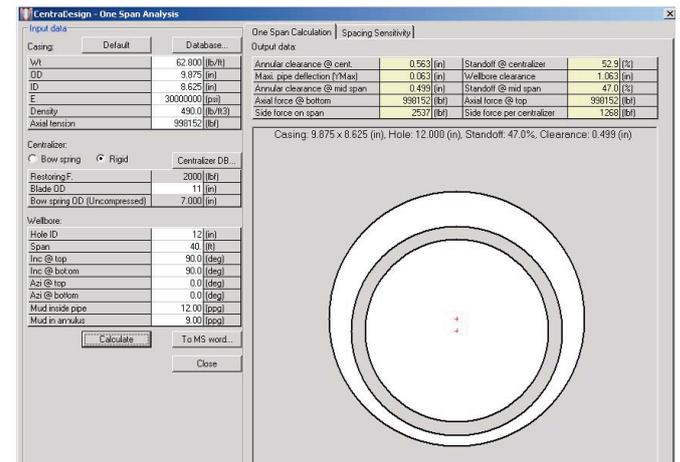


Figure 6. Centraliser placement.

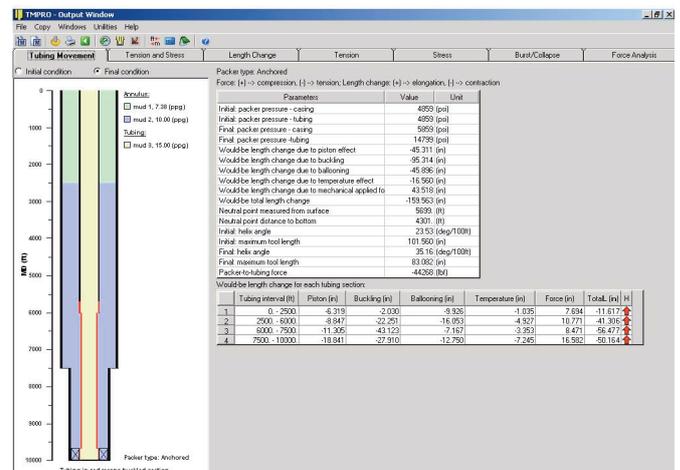


Figure 7. Tubing movement.

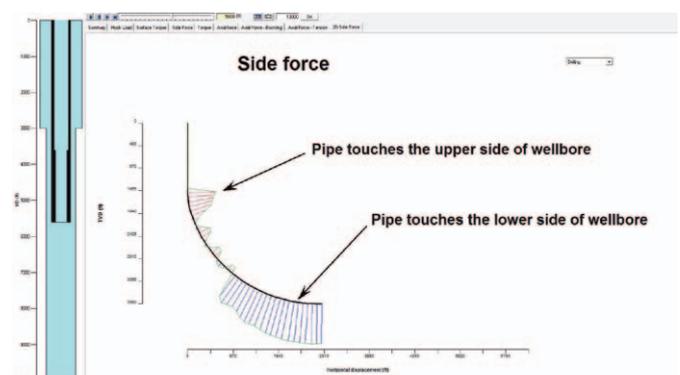


Figure 8. Side force distribution.

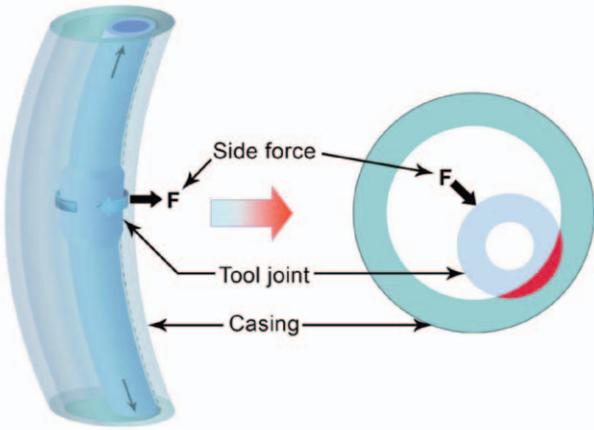


Figure 9. Casing wear mechanism.

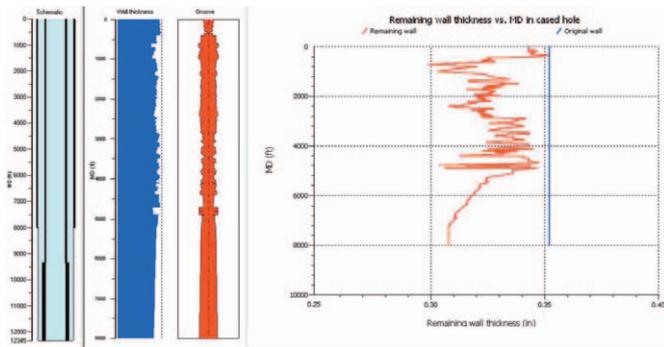


Figure 10. Wear profile.

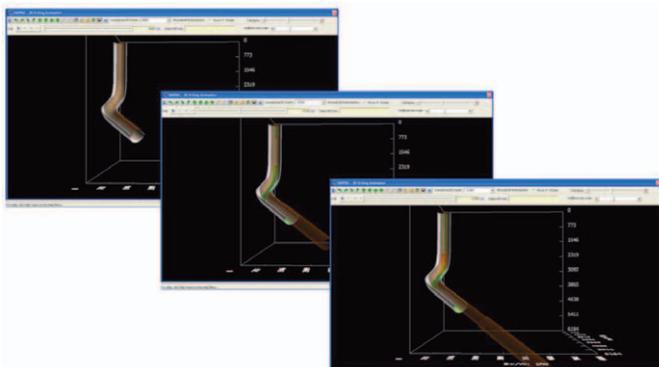


Figure 11. Casing wear animation (CWPRO output).

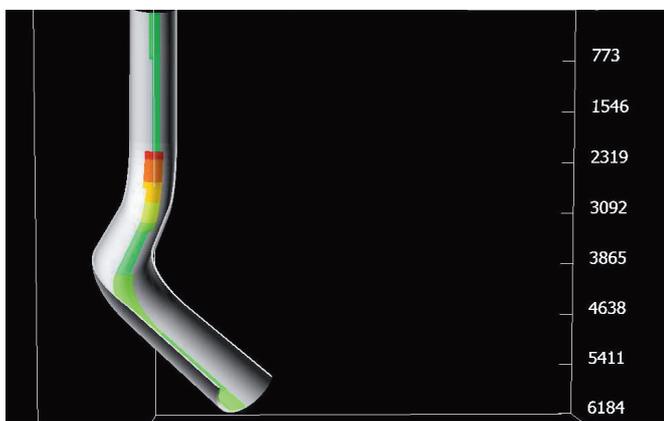


Figure 12. Final 3D wear profile.

This process can be computer modelled and the wear profile can be displayed as shown in Figure 10.

As one can imagine, casing wear deepens as the well is drilled deeper. It is a time-dependent incident. Figure 10 shows the sequence of drilling and the corresponding wear profile along the previously set casing.

Generally speaking, high dogleg will create high side force and will create severe casing wear. The wear profile resembles the shape of dogleg severity. Higher RPM and lower ROP make more rotation time between tool joint and casing and will cause aggressive wear. Using graphics and 3D visualisation makes understanding and prediction easier.

Drilling mud reporting

Historically, mud engineers used paper forms to record mud properties every morning. With the introduction of Excel and other similar software, people began to take advantage of electronic filing. This greatly enhanced the reporting and filing quality. However, the critical part that is missing from this approach is probably the organisation of numeric daily reports and generation of end-of-well recaps. Not to mention well comparison, which requires obtaining histories of drilling activities over periods of time of multiple wells in various geographical areas.

The modern approach in mud reporting is to use software with the database backbone to perform solids analysis and hydraulics calculations, as well as keep track of all inventory and costs and quickly generate reports. By looking at the end-of-well recap, the most costly drilling intervals can be identified and the necessary modifications to mud programmes can be made for the next well.

Mud reporting software can streamline the mud operation using case studies. Typical mud reporting software not only keeps track of inventories and costs, but also performs hydraulics calculations and creates daily reports at the click of a button. With the help of a database engine as a backbone, this software can handle multiple wells at the same time, so that well comparison becomes an easy routine.

Conclusion

Drilling software is such an enabling technology that it can elevate entry-level engineers and amplify the experience of seasoned ones.

These software models can also serve as a valuable educational tool for new engineers without much experience in the field: they can learn from the software first. Utilising software allows engineers to identify potential trouble spots. If problems do arise, the software can help solve them before they get out of hand.

During the oil well drilling phase, cost overruns can easily occur due to unexpected issues related to pipe failure (torque and drag), loss of circulation (hydraulics), etc. These issues result in non-productive time (NPT), which is much more detrimental than the cost of a certain failed part. Considering the potential cost overruns, it is reported that oil companies sometimes earmark 10% to 25% of the AFE to cover the unexpected costs.

Software makes drilling design and analysis more transparent and visible to everyone. Through being able to see better and deeper, one can reduce both risks and costs whilst increasing success rates. 