

Managing stick-slip

Mats Andersen, Stephen Forrester, and Andrew Creegan, of NOV, discuss how to overcome potentially damaging stick-slip issues and improve drilling performance rates.

Stick-slip, a mode of drilling dysfunction characterized by a cycle of the bit coming to a stop and accelerating to speeds greater than the mean bottom-hole assembly (BHA) speed, has become an important risk element in oil and gas drilling operations. Awareness of stick-slip, which is largely a vibration-related phenomenon, has increased in part due to the rise of polycrystalline diamond compact (PDC) cutters that drill through rock with sheer rotary force. When stick-slip occurs at the end of a drillstring, the resultant release of accumulated energy causes extra twist in the string, which can cause severe bit damage. This can happen during both torsional and lateral vibration during the stick and slip phases.

Combating stick-slip is critical to improving performance, increasing drilling efficiency, and enhancing equipment life. Stick-slip can cause significant wear to the outer cutters of drill bits and excessive heat checking, leading to more bit runs per section and a higher frequency of bits that are damaged beyond repair. Overall drilling performance can be decreased due to persistent stick-slip, as the amount of energy transmitted from the topdrive to the bit is greatly diminished. Cutters engage with less consistency and torque-on-bit fluctuates,

while rate of penetration (ROP) decreases and mechanical-specific energy increases. Premature bit wear, measurement while drilling (MWD) tool failure, and motor failure are also potential problems due to the damaging vibration seen in the slip phase. To deal with the issue of stick-slip and increase drilling efficiency, National Oilwell Varco (NOV) developed and commercially deployed the SoftSpeed II stick-slip mitigation system.

Stick-slip mitigation system

NOV's SoftSpeed II system is a software application added to the topdrive

controller that manipulates topdrive RPM to absorb torsional energy transmitted to surface and reflects only a portion of the energy back. After several iterations of this, vibrations are dampened and the string becomes stable. Generally, increases in torque yield decreases in RPM, and vice versa, which is known as destructive interference. When the driller activates the SoftSpeed II system, the system's analyzer continually identifies, quantifies, and alerts the driller to torsional vibrations. If the stick-slip severity indicator on the driller's screen shows a degree of stick-slip, the driller can activate the SoftSpeed II system to provide optimal damping to mitigate those stick-slip occurrences.

The conventional method of mitigating stick-slip is increasing RPM and/or decreasing weight on bit (WOB), which is inefficient and can induce bit-damaging lateral vibration. By using the SoftSpeed II system, higher WOB can be achieved at a given RPM before stick-slip foundering occurs (Fig. 1).

In addition, using the system eliminates the need to employ more traditional methods of mitigating stick-slip. In the past, bit design would be made less aggressive, with smaller cutters and more blades leading to depth-of-cut limitations and increased back rake. The BHA could also be redesigned with fewer stabilizers, or parameters could be manually manipulated by the driller to increase RPM and decrease WOB. While these methods proved somewhat effective, they frequently resulted in decreased ROP and higher overall well costs.

Alternating current (AC) topdrives apply the appropriate amount of energy needed to maintain an RPM setpoint, while the drillstring acts as a transmission line for torsional energy waves. The SoftSpeed II system tunes the drive to catch such waves by absorbing them, which is possible due to the stick-slip period having been predicted by the system's calculations. The system determines the stick-slip period by modeling the drillstring as a torsional spring-and-mass system and calculating stick-slip

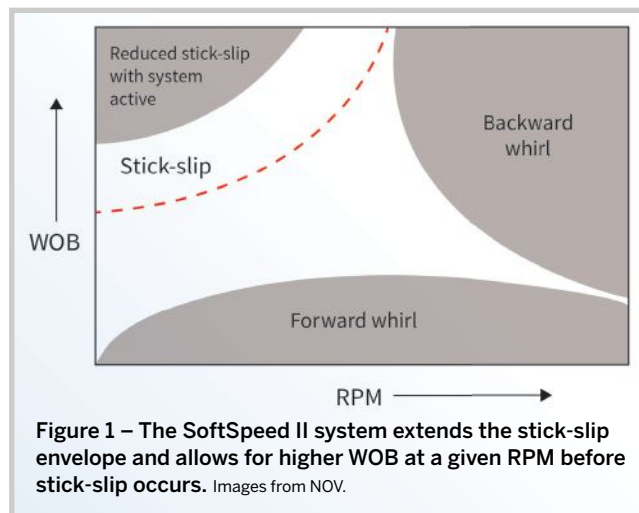


Figure 1 – The SoftSpeed II system extends the stick-slip envelope and allows for higher WOB at a given RPM before stick-slip occurs. Images from NOV.

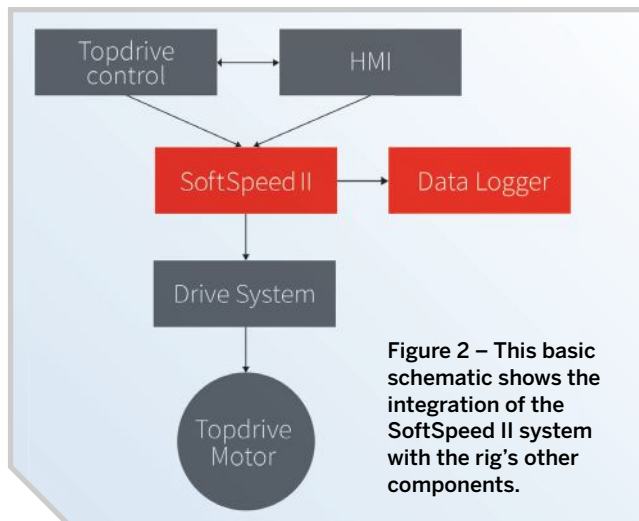


Figure 2 – This basic schematic shows the integration of the SoftSpeed II system with the rig's other components.

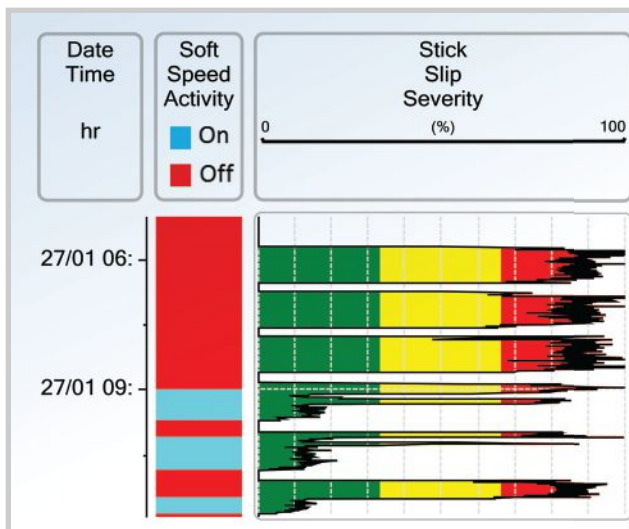


Figure 3 – This graph shows a comparison of stick-slip severity with the SoftSpeed II system on and off. With the system inactive, severity levels are seen to be high; while active, severity levels are low, indicating smooth drilling.

frequency, which is modified based off of torque feedback. The stick-slip period is determined automatically, and the system informs the user of the estimated BHA speed.

Case history

An operator drilling in the North Sea was suffering periods of extreme stick-slip in their 8½-in. horizontal section. Stick-slip severity was seen to be at a level indicative of true stick-slip for an extended period of time before initializing the SoftSpeed II system. System activation allowed the rig to drill in a much more efficient manner, thus increasing ROP, decreasing downhole equipment fatigue, and lessening the risk of a catastrophic event such as a drillstring twist-off.

Rig components/software integration

The North Sea client had the SoftSpeed II system integrated into the rig's topdrive controls, which then synchronized with other components across the rig. The full system, outside of the SoftSpeed II software algorithm itself, on the subject rig is as follows (Fig. 2):

1. Human-machine interface (HMI): The HMI is part of the Amphion integrated control system, which allows operation of the SoftSpeed II software, visualization of drilling parameters, and input of pipe tally values.
2. Topdrive control: This is the control system for the topdrive.
3. Drive system: The drive system is a variable frequency drive (AC) that controls the topdrive motor.
4. Topdrive motor: The topdrive motor reads the inputs from the SoftSpeed

II system and provides the necessary output to vary pipe rotation to automatically mitigate stick-slip based on the software model.

5. Data logger: The data logger records relevant topdrive and SoftSpeed II system parameters at 100 ms/10 Hz for diagnostics and performance checks of the system, making the data available for further analysis.

Commissioning

A dedicated commissioning and setup procedure was developed for this project. NOV deployed a field-service technician and project engineer to the rig site to install the software, map the visualization channels, and commission the system. This required access to the topdrive without pipe in it and was accomplished during scheduled downtime. During commissioning, the engineer remained with the drilling crew to ensure proper training on the system's functionalities. Upon completion of this phase, the software was linked to a real-time technology center to enable constant monitoring of the system, allowing onshore engineers instant insight into performance metrics. Having this knowledge helped NOV provide the client with daily reports, which included information such as stick-slip severity by depth and calibration and tuning specifics, to their office. In addition, the reports confirmed that WOB, ROP, torque, and RPM properly correlated with downhole conditions.

Implementation and results

Upon implementation of the SoftSpeed II system, the rig saw a marked improvement in drilling performance. With the

system largely inactive, stick-slip severity levels were seen to be near 100%. This level of drilling vibration, which represents a true stick-and-slip cycle, is known to be damaging and inefficient. The rig coped with this level of stick-slip for 39 hours, drilling at an average ROP of 19m/hr (62.3ft/hr). The decision was then made to run the SoftSpeed II system consistently, with vibration levels greatly mitigated as a result. Over the next 24 hours, the rig saw stick-slip severity levels drop to "Level 1," which indicates smooth downhole rotation. It was also noted that the ROP for this period had increased by 2m/hr (6.6ft/hr) to 21m/hr (68.9ft/hr). This allowed the rig to drill approximately one and a half extra stands in that day compared to the prior drilling rate, when vibration was high and drilling less efficient. **OE**



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