OILFIELD TECHNOLOGY

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TAKE CONTROL OF DESTRUCTIVE VIBRATIONS

COVER STORY

Volker Peters (Germany) and Daniel Bell (USA), Baker Hughes, describe the challenge of HFTO, and how a new torsional dampener tool can suppress oscillations and improve operation.

The ability to drill longer horizontal wells and laterals improves well economics but pushes the technical limits of bottomhole assemblies (BHAs) in complex well designs. A key challenge introduced is high-frequency torsional oscillation (HFTO): self-excited vibration resulting from bit/rock interaction that can cause premature damage to drilling tools and components, leading to increased capital costs and unplanned downtime. Engineers have been working for decades to understand and resolve HFTO, but until recently, tools designed to mitigate vibration have been only marginally successful.

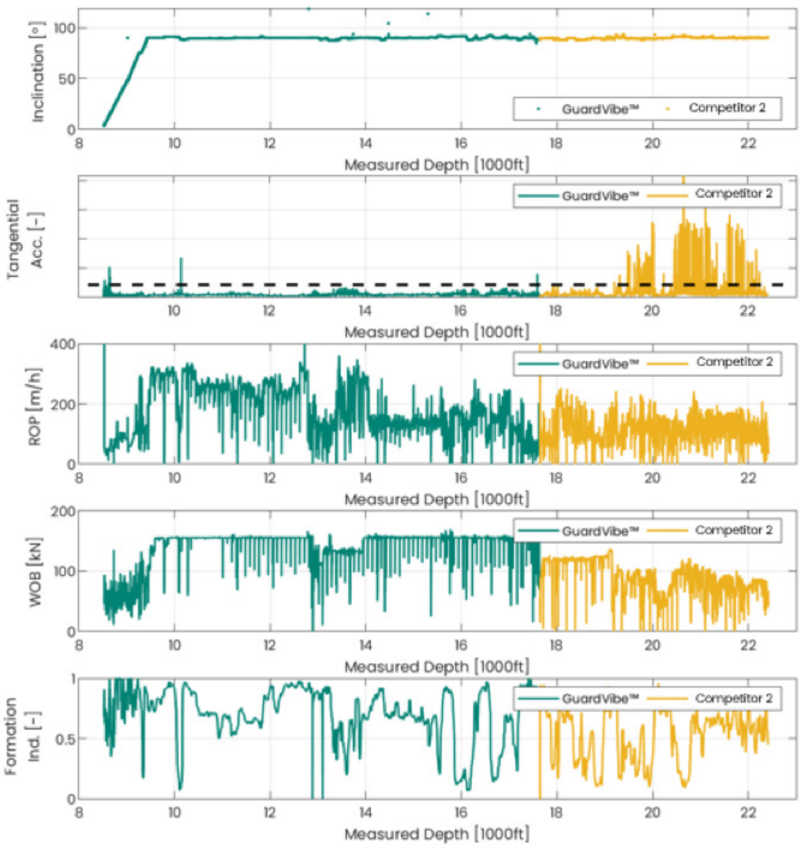


Figure 1. *Depth based averaged surface and downhole data. (Image courtesy of Baker Hughes). Graphic is from SPE-217677-MS 'Effectiveness of HFTO-Dampener Assembly Proven by Extensive Case Study in Permian Basin' presented at the IADC/SPE International Drilling Conference and Exhibition, Galveston, Texas, March 2024, https://doi.org/10.2118/217677-MS*

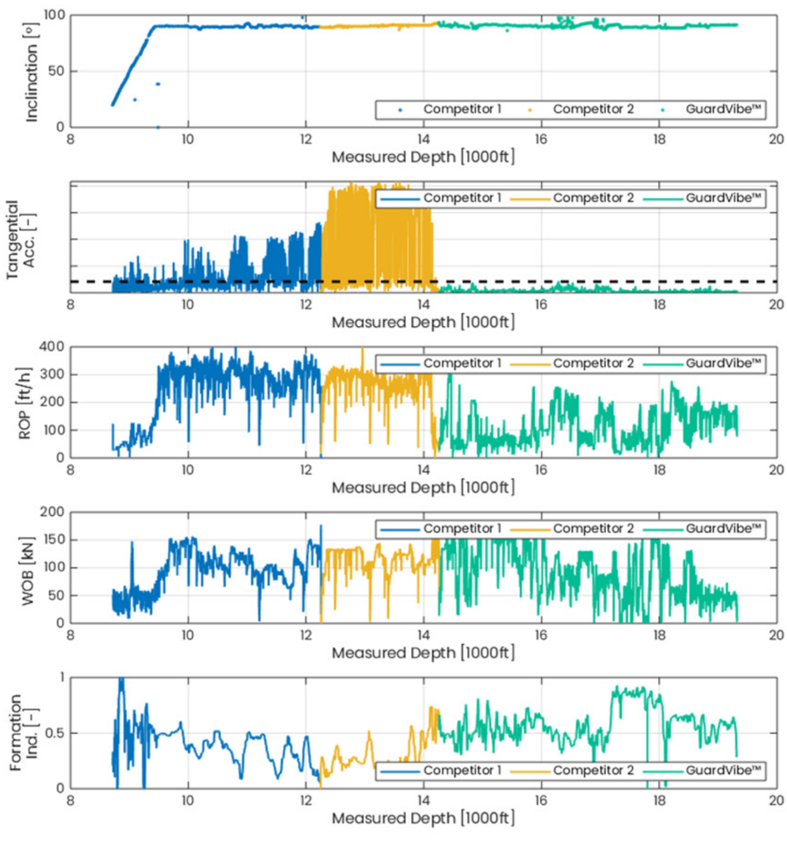


Figure 2. *Depth based averaged surface and downhole data. (Image courtesy of Baker Hughes). Garphic is from SPE-217677-MS 'Effectiveness of HFTO-Dampener Assembly Proven by Extensive Case Study in Permian Basin' presented at the IADC/SPE International Drilling Conference and Exhibition, Galveston, Texas, March 2024, https://doi.org/10.2118/217677-MS*

HFTO and traditional solutions

HFTO typically occurs in the BHA, generating dynamic oscillations in the range of ~50 Hz to ~400 Hz. The vibration motion-induced twist in the drill string causes dynamic torque, which increases the load on drill string components. One of the unfavourable consequences is premature fatigue damage of tools and components, resulting in slower drilling for mitigation and more nonproductive time (NPT). Another is damage to sensitive components – such as sensors, electronics and even connectors and electrical wires – caused by acceleration.

Many tools that claim to address HFTO have had limited success because they focus exclusively on managing bit induced stick-slip, which is caused by the bit-rock cutting interaction and results in drill bit rotation alternating between periods of slowing down and suddenly accelerating. Stick-slip tools, placed above the BHA, reduce stick-slip vibration between axial and torsional degree of freedom via a mechanical coupling (a spline connection or wire ropes) to initiate axial motion when torque changes occur. The tools themselves mitigate vibration by reducing the depth of cut through reduction of weight on bit (WOB).

If HFTO is not mitigated properly, WOB and/or bit rpm has to be reduced to limit vibrations to acceptable levels, which in turn reduces rate of penetration (ROP). Costly reductions in ROP are impediments for achieving optimal field economics, but an equally significant problem with such axial-torsional coupling tools is that they focus primarily on stick-slip, and only occasionally reduce levels of HFTO. The result is that, although these tools have proven marginally successful in reducing HFTO, in instances where downhole conditions demand higher dampening, the tools are unable to resolve it.

Taking a different approach

The shortcomings of traditional tools that address HFTO led Baker Hughes to invest in research to better understand what happens downhole to incite excessive vibration and how models could be developed to better comprehend it. Employing the results of this research, engineers designed a torsional vibration dampener tool that is purpose built to suppress all modes and instances of HFTO for all drilling parameters employing a novel design with no load bearing components that have differential motion, unlike the axial - torsional coupling.

The unique tool is one rigid piece that is affixed to the BHA. It has no parts requiring grease-filled compartments that need to be protected with dynamic seals like some stick/slip solutions. This design eliminates reliability concerns because there are no moving mechanical parts, bearing drilling load. Torque and drilling nodes are fed through rigidly connected collars.

The function principle is based on an internal inertia mass that can freely rotate with respect to the centre of the drilling system but is connected to the BHA by a dissipative force. When no torsional vibrations are present, the inertia mass rotates together with the BHA. In the presence of HFTO, inertia mass resists the motion of the vibration. Designed and built to suppress HFTO holistically, this tool creates sufficient dampening in a frequency band of 50 – 500 Hz.

The dampening tool is most commonly run on top of the BHA, although in cases where a downhole motor is used, the dampener is placed below the motor. In either configuration, the tool is handled like a regular drilling tool, with no need for special setups or electrical configurations. Due to its design and placement on the BHA, the dampener does not compromise formation evaluation sensor positioning or the steerability of the rotary steerable system.

This unique technology enables dampening of high-frequency torsional oscillations for the entire BHA, which provides several benefits to the drilling operation. It extends the operating life of the BHA, improves stability, efficiency, and directional control while drilling through transitions, achieves higher ROPs by not holding back ROP because of vibration, and extends run life downhole. It also expands the drilling envelope by allowing harder formations to be drilled without reducing the drilling parameters.

To ensure vibration dampening is sufficient, specifications for the entire BHA string that will be used on the drilling job are entered into a software model, and a piece of code adapted for the software optimises the placement and the performance of the dampening devices. The software tries different numbers of devices and all possible configurations and selects one in which the efficiency of the dampeners is maximised for all anticipated scenarios. Tools are positioned according to dampening demand, and engineers can tailor parameters and performance outputs as HTFO levels increase and can dampen them appropriately, so they are not damaging or obstructive. This level of performance is not achievable with other vibration mitigation tools.

All Baker Hughes dampener tools are laboratory tested to extremes for durability and reliability using cyclic bending, shock and vibration, temperature, pressure testing methods. Functional testing of dampening performance is executed with scaled lab samples using multiple sensor elements.

The entire BHA, with the torsional vibration dampener attached at the top of the drilling BHA (but below the mud motor if one is used) is preconfigured for the job. The appropriate vibration dampening configuration is delivered to the rig site as one piece ready to install. The presence of the tool on the BHA does not restrict drilling in any way. The only noticeable difference between a BHA without the tool and a BHA with the tool is HFTO suppression.

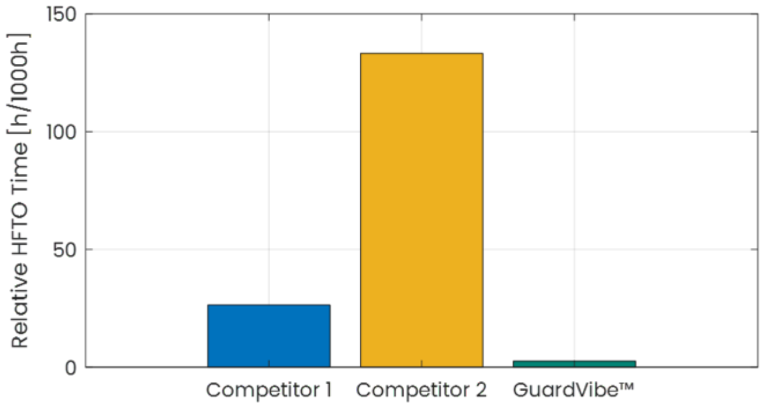


Figure 3. *This chart shows the amount of HFTO time per circulating time for runs using the two competitor vibration mitigation tools and the GuardVibe HFTO tool. (Image courtesy of Baker Hughes). Graphic is from SPE-217677-MS "Effectiveness of HFTO-Dampener Assembly Proven by Extensive Case Study in Permian Basin" presented at the IADC/SPE International Drilling Conference and Exhibition, Galveston, Texas, March 2024. https://doi.org/10.2118/217677-MS*

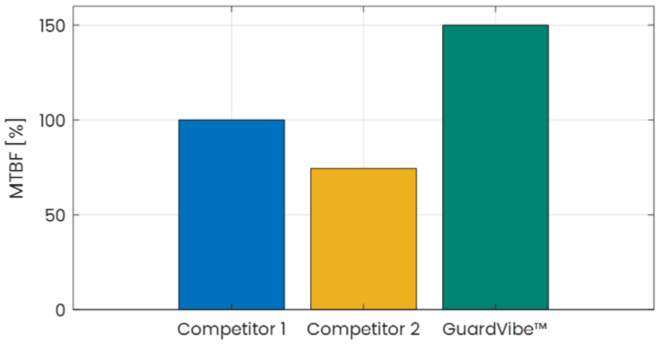


Figure 4. *Mean Time between Failure (MTBF) of the BHA. Graphic is from SPE-217677-MS 'Effectiveness of HFTO-Dampener Assembly Proven by Extensive Case Study in Permian Basin' presented at the IADC/SPE International Drilling Conference and Exhibition, Galveston, Texas, March 2024, https://doi.org/10.2118/217677-MS*

Field applications deliver results

Field tests over the course of more than 350 drilling runs, primarily in harsh environment conditions in the Midland and Delaware sub-basins in the Permian Basin – where extended reach drilling is common – delivered 98% of the circulation time free of HTFO.

Results from two of these field implementations illustrate how the torsional vibration dampening technology performed in real-world conditions in comparison to other HTFO management tools on the market.

In the first application, the Baker Hughes GuardVibe™ high-frequency torsional oscillation dampener technology was employed in the first instance in the curve and drilled the first part of the lateral section (Figure 1). The BHA was tripped because of bit wear and low ROP, and in a second run, the proprietary HFTO tool was used again in the lateral section. In both runs, the BHA experienced nearly no HFTO and maintained an ROP between 300 ft/hr and 120 ft/hour. In the second run, there were slightly increased levels of tangential acceleration between 13 000 ft and 14 000 ft, indicating that the GuardVibe HFTO tool was dissipating energy to prevent HFTO from rising to its plateau amplitude.

In Figure 1, the green tracks represent data acquired from runs with the GuardVibe HFTO tool. The yellow tracks represent data from a run with a commercially available stick-slip tool. Tangential acceleration (HFTO), represented in the second track from above, is mitigated and suppressed using the GuardVibe HFTO tool. Conversely, HFTO is largely present using the commercially available stick-slip tool. For reference, ROP, WOB and rock formation properties are displayed as well, in the three bottom tracks.

After a motor failure at the end of the second run, a different vibration mitigation tool was deployed (Competitor 2). The results using this traditional tool were suboptimal, with high HFTO levels throughout the run, which negatively impacted ROP. Using the traditional tool also required WOB to be reduced to mitigate vibration. The formation values in this run were similar to those where the GuardVibe HFTO tool had been deployed, indicating that downhole conditions like these are likely to produce high HFTO levels, which can be successfully suppressed using the proprietary technology.

In a second application, the GuardVibe HFTO tool was benchmarked against vibration mitigation tools from two other vendors (Figure 2). A load sensor mounted on the BHA measured dynamic torque, while accelerometers positioned in two areas – one next to the load sensor and the other farther up the BHA – measured tangential acceleration amplitude and dominant frequencies.

The first run was drilled with the tool from Competitor 1, the second run was drilled with the tool from Competitor 2. The third and fourth runs were drilled with the GuardVibe HFTO tool. All runs were conducted in the lateral section.

In Figure 2, the blue and yellow tracks represent data from separate runs using two commercially available stick-slip tools. The green track represents data acquired from runs with the GuardVibe HFTO tool. Tangential acceleration (HFTO), represented in the second track is mitigated and suppressed using the GuardVibe HFTO tool, but HFTO is largely present using the two commercially available stick-slip tools. For reference, ROP, WOB and rock formation properties also are displayed in the three bottom tracks.

The BHAs for both Competitor 1 and Competitor 2 experienced high HFTO-related loads, with different levels/plateaus of tangential acceleration measured. This was caused by different dominant HFTO frequencies between 200 Hz and 300 Hz. The GuardVibe HFTO tool, on the other hand, mitigated HFTO to amplitudes close to zero. Even in formations that were tougher to drill, represented for example by the section between 14 000 and 16 000 ft, indicating a harder rock formation, where WOB was set to high levels but resulted in comparably low ROP, the GuardVibe HFTO tool eliminated HFTO altogether.

To carry out benchmarking, 44 runs were drilled using the proprietary tool, 113 runs were drilled with the vibration mitigation tool from Competitor 1, and 39 runs were drilled with the vibration mitigation tool from Competitor 2 (Figure 3 and Figure 4).

In this case, the vibration mitigation tools were placed between the mud motor and the wired part of the BHA. All the runs were carried out in comparable target formations, with similar PDC bits and BHAs.

The duration of HFTO in hours per 1000 hr circulating time for the vibration mitigation tools is shown in Figure 3. The GuardVibe HFTO tool experiences close to zero time with HFTO. The runs with Competitor 1 experienced an average of more than 26 hours/1000 hours drilled, and the runs with Competitor 2 experienced an average of more than 138 hours/1000 hours drilled.

It is important to recognise that the reliability of this tool and the reliability of the other BHA components are all important for project economics. In this drilling programme, the runs using the GuardVibe HFTO tool had a significantly higher reliability with Mean Time Between Failures (MTBF) at least 100 % higher than Competitor 2 and about 50 % higher than Competitor 1 for the complete BHA, including the dampener tool (Figure 4, MTBF).

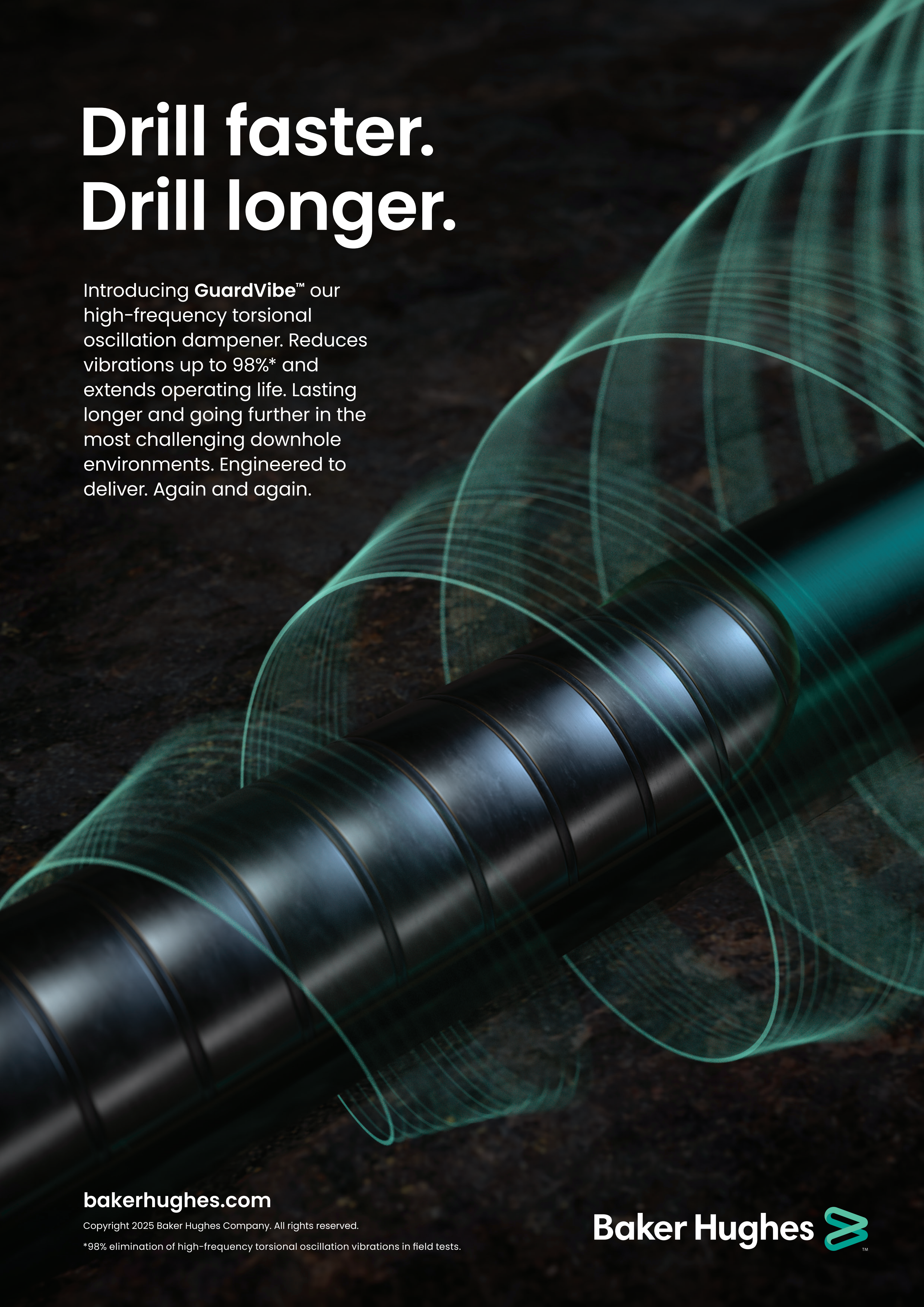
MTBF is a key performance indicator of NPT and represents cost drivers in drilling operations. Figure 4 shows that mitigation of HFTO exposure directly correlates to reliability measures of the drilling BHA. The runs using the GuardVibe HFTO tool experienced close to zero HFTO (eg ~twice MTBF achieved using the tool from Competitor 2, which had the highest percentage of HFTO). The intrinsic, high reliability of the dampener tool design, along with its ability to mitigate HFTO, are key to the excellent overall performance in the application.

What's next?

Thus far, nearly all of the tool installations have been in the Permian Basin using 4.75 in. tools, which creates a compelling case for employing the technology elsewhere. Already, the technology is being used extensively in drilling applications in Argentina, and there are opportunities in the Eastern Hemisphere – in drilling programmes in areas like China and Saudi Arabia where HFTO is a challenge – where this technology could significantly improve performance.

Designed to be agnostic, this tool can be used in all rotary steerable drilling applications. Recent field deployments in Saudi Arabia have proven effective in conjunction with complex MWD/LWD (Triple Combo) drilling BHAs. Unlike the deployments in the Permian Basin, the drilling runs carried out in Saudi Arabia were performed using a rotary from surface, without a drilling motor. This is a significant achievement because in Saudi Arabia, where drilling with advanced LWD tools is common and drilling programmes are non-motor assisted, traditional HFTO solutions have been either inefficient (stick-slip mitigation tools) or have displayed other deficiencies, like reducing torque throughput or increasing sensor offset.

As more data is gathered from more drilling environments, it will be possible to tailor solutions for a broader range of applications and in time, develop additional tool sizes to enable more efficient drilling programmes in every corner of the world.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