Ztorque

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Ztorque introduction

Ztorque (Zt) is a Shell developed torsional vibration mitigation system. Zt is a wide band impedance (Z) matching concept, which requires no tuning. The technology is based on transmission line theory with underlying ambition to absorb all torque waves arriving at the top drive. This in contrast to the original 'classic' Soft Torque Rotary System (STRS) which is focused on absorbing torque waves of the first vibration mode and needs regular (stand by stand) tuning as the well deepens.
In summary, Zt has 2 main advantages:

1. Wide band ability to absorb torsional vibration modes for most drilling conditions
2. No tuning required

The ability of the system to perform across the bandwidth is determined by the system design and hardware available on the rig. The operational performance of such a system can be analyzed using control system analysis techniques.
The key performance indicator used is called the 'Hummingbird plot'.

General system design overview

The Zt system is a control system of the top drive motor resulting in an RPM behavior that aims to absorb 'all' torque and speed waves arriving at the top drive (saver sub). The control system changes the hard boundary condition into a boundary condition that resembles an 'infinite' drill string continuing 'above' the surface. In other words: the boundary condition is eliminated. A standard top drive RPM controller is stiff and results in full reflection of all torsional waves which causes growth of standing waves in the string which eventually may lead to stick slip at the drill bit and/or motor housing/BHA. Classic soft torque partly absorbs and partly reflects torsional waves of the first mode to which it is tuned specifically, and needs to be continuously tuned as the drill string deepens. These various behaviors can be easily identified in the Hummingbird plot, where the reflectance is given as function of frequency, see below schematic Hummingbird plot (Fig 1):

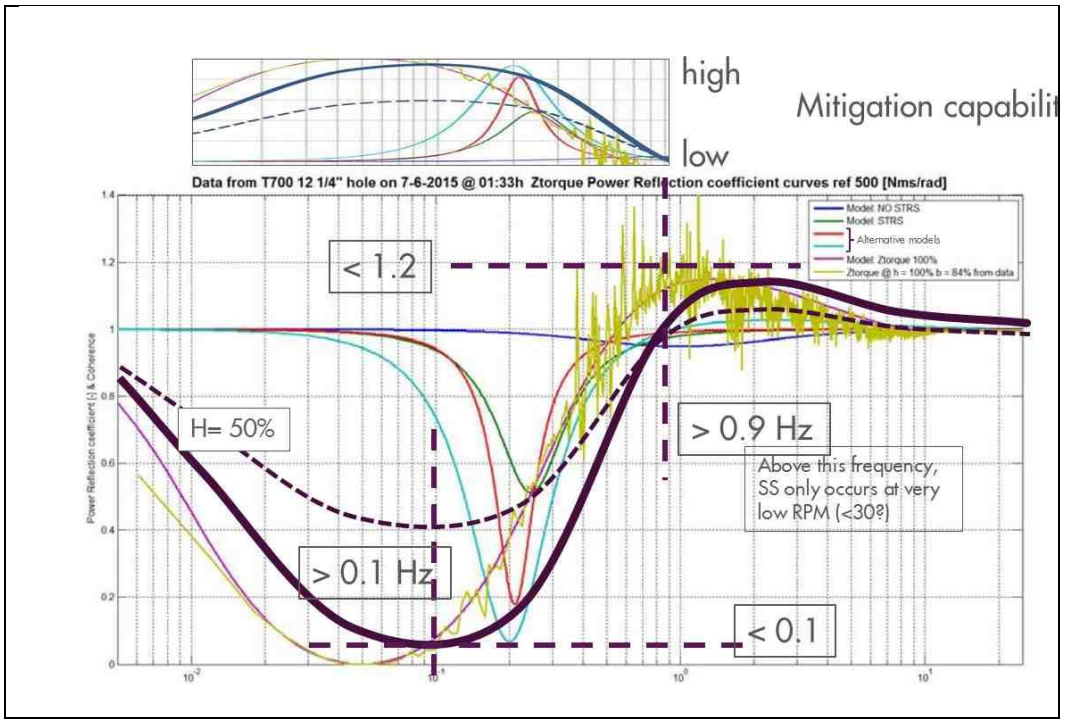

Fig 1 Conceptual Hummingbird with specifications

The stiff top drive characterization is given as the blue curve, the classic STRS (tuned to a given depth) is shown as in green and the Zt response as the dark heavy curve (with “hummingbird” shape).
The Zt controller uses feedback from sensed Torque and Speed which ideally would come from a theoretical ‘ideal’ instrumented Saver Sub, however in practice is derived more conveniently from the existing rig sensor systems in combination with the top drive power supply system called the VFD.
In order to absorb the torque and speed wave arriving at the top drive, the system has to match the fluctuation of the arriving ‘wave’. (In case the matching is not perfect, there is partial absorption, and partial reflection). This requires a rapid acceleration response from the top drive for which additional torque needs to be supplied to overcome the inertia of the motor and gearbox, the so called ‘inertial torque’. For a normal stiff top drive, there is a constant RPM, and thus no acceleration is present, and the pipe (saver sub) torque is identical to the motor torque seen conventionally by the driller on his monitors. Thus when using Zt we need to distinguish between Motor torque and actual Pipe torque, whereby the difference is calculated from acceleration and top drive inertia.
The need to correct for inertia on the motor torque input is called ‘Inertial correction’, and is limited by the ability of the drive to fulfill the required acceleration. Obviously at higher frequencies, this is not possible, which explains why the ability to absorb the wave (minimum at the belly of the hummingbird) slowly diminishes as frequency increases and may eventually results in over compensation (adding energy) in the frequency range where the ‘head’ is evident as an undesirable artefact of the system.

Functionality

1. A driller's HMI with ability to switch on/off and enter parameters Z, and H%.
   Runs in 'ABS/auto-on' mode such that it is automatically switched on while drilling activities are of the type that torsional mitigation is required, and 'auto-off' when system is not required and/or may interfere with non-drilling rig activities.
2. Display pipe torque and perform dynamic torque limiting. Pipe torque parameters are displayed and exported as default surface torque signal for the driller and remote monitoring systems
3. Ability to extract data to run the hummingbird evaluation scripts.
4. hi-speed data recorder with minimum frequency of 100Hz, with antialiasing filtering and data recording capability for a rolling 6 months, using flash memory (no hard disks)
5. Ability to output WITS data as specified in the Shell STRS WITS spec 2015.
6. Ability to provide a standard output data file (format defined in the commissioning protocol) with option to provide a short formatted file for troubleshooting, of max 10 MB, suitable to be sent by Email

Operating the commissioned system

The driller will use the system, by selecting the relevant drill pipe size/weight (giving the 1/Z value) and applying an intensity value H% based on regional experience (see below). Once set, the system will be switched on and run automatically without any tuning required, until the Driller switches it off, or it is switched off automatically due to low RPM set point (a functionality to allow using the top drive for other rig activities).

<u>Selection of intensity (H%) value:</u>

Although the theoretical ambition of Ztorque is to absorb all torque/speed waves, in practice this can only happen at the 'belly' (theoretical value 0) of the hummingbird (ie over the lower frequency band which usually corresponds to the 1st mode). In addition, setting H% to 100 also can cause the system to induce high Top drive RPM activity, which may cause clipping and/or other undesired top drive response (both torque and speed). Therefore in practice it is recommended to set the system to a moderate H% of around 30-50%, until local experience has established what the optimal setting may be for the given drilling assembly and the formations being drilled. Note these settings will be relevant for that particular rig (with related top drive and VFD), and may vary across the fleet .

Thus the operating procedure will be:

- At start of section, driller sets the characteristic impedance according to the table:

Drill Pipe size	1/Z (Characteristic impedance
6"	1000
5.5"	500
5"	428
4.5"	300
4"	200

- Driller sets the intensity to the desired (regional) value H% 20-100. Depending on level of mitigation achieved, driller can raise or lower the value.
- If driller desires, system can be switched off by dialing H=0%

Pipe torque and dynamic torque limiting concepts.

The driller will set torque limits for pipe based on the pipe torque concept and the dynamic torque limiting option will be operational (as standard setting). During initial use of the system, the driller will need to become familiar with the much more active behavior ***(liveliness)*** of the system, whereby there are possible large swings in surface RPM and high (motor) torque variations. It will be apparent to the driller that the pipe torque however is much smoother and he should see lower/mitigated vibration signals from his down hole tools.

In the case that the driller is unhappy with the behavior being too extreme at surface, he always has the option to reduce the H% (and ultimately setting to zero will effectively switch the system off). However in that case the pipe torque curve will likely show increased amplitude compared to the motor torque, indicating that torsional vibrations are present at the saver sub/drill pipe and that mitigation is required (even if the 'liveliness' behavior appears undesirable). Down hole vibration data will also be a good reference to evaluate mitigation and H% setting by.

The final commissioned Zt system gives the driller a Stick Slip mitigation tool; however the overall performance is dependent on the drill string attached. For most conventional drilling conditions the system will perform as required, however for -very short or- more complex strings, particularly with varying drill pipe and BHA sizes (eg tapered strings), the system will not necessarily perform adequately, and down hole data may show that mitigation is unsuccessful. In such a case, the system H setting can be reduced. Setting that H value to zero is the equivalent of not using the system at all.

PERFORMING BETTER

QATAR: IMPLEMENTATION OF Z-TORQUE ON NF-12 IN QATAR

Z torque has been successfully installed on GDI-8 to suppress stick slip by maximizing the top drives ability to catch the torque waves travelling through the drill string from the bit. This is a different approach compared to SoftTorque which treats the complete drill string as a mass-spring-dampener. Z-Torque increases the mobility of the top drive and counteract torque variations with velocity swings, absorbing the torque waves at the saver sub and preventing them from bouncing back to the bit. This levels the speed and reduces or eliminates stick slip.

GDI-8 is the first drill rig where ElectroProject has implemented Z torque according to Shell's patent in the top drive VFD. A fast bus is installed to allow communicating quickly enough to analyze and counteract with speed correction from controller. The theoretically mobility of the Z-torque without time delays is very good, and thus the requirement for the fast bus. The Z-torque systems widens the window for stick-slip free drilling and is more user friendly as it does not need constant re-tuning against actual drillstring length. Simply turn it on!

For more information, contact QSSC-Onshore-Perf-AA@shell.com (A&A Performance Team)