Offshore Drilling Analysis Solutions – Directional Drilling, Drillstring Mechanics and Fatigue Analysis Services and Software

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INTRODUCTION

DrillScan is a French company that provides services and software to the drilling industry. Its expertise is based on the results of 30 years research carried out at the Mines ParisTech university, and large laboratory and field validations in collaboration with operators. Thanks to its high quality and advanced modelling software, BHA Management® (see figure 1), its highly skilled team and close collaborations with Total, DrillScan provides solutions in the field of directional drilling, torque and drag, buckling, drilling bit performances, dynamics and wellbore placement. The aim of this technical paper is to present the sophisticated modelling and methods of software of BHA Management®, and some field applications that have led to improved drilling performance. In this paper, one will focus mainly on drilling mechanics, and more specifically on directional drilling, drill string mechanics and fatigue issues in offshore environments.

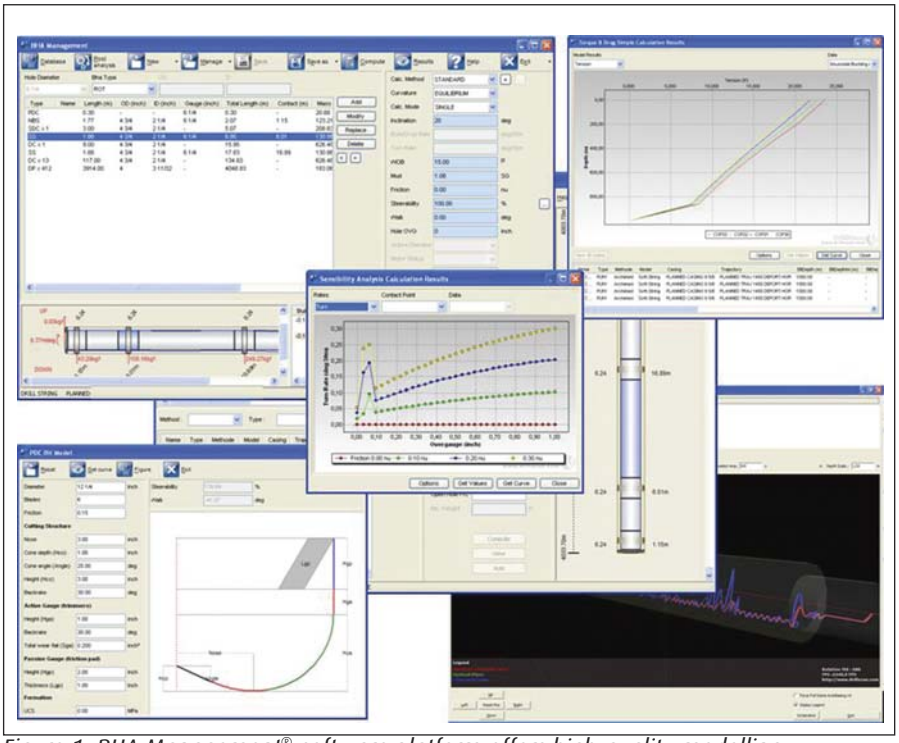

Figure 1: BHA Management® software platform offers high-quality modelling

BHA-DrillString/Hole contact points, are fully assessed by the model, using a powerful iterative process

OFFSHORE DRILLING

Even though offshore drilling techniques are generally similar to those onshore, drilling an offshore well is always very challenging, and more difficult than an onshore well. This complexity comes obviously from the rig platform structure itself, but is also due to the very challenging well paths required to hit multiple targets. Indeed, because of the complex and deep well trajectory, offshore equipment and technology must be adapted to meet this harsh, high-cost environment. As a consequence, drilling complex offshore wells requires accurate and sophisticated predictive modelling, to reduce risks and lower drilling costs.

DIRECTIONAL DRILLING

The oil and gas industry relies greatly on directional drilling to develop petroleum reserves in high-costs environments such as deepwater offshore. To address directional performance issues in these complex wells (3D, Extended Reach Drilling, High Pressure / High Temperature Wells, Ultra Deep Water), Bottom Hole Assemblies (BHAs) become more complex and sophisticated. To be able to accurately predict the directional behaviour of these complex BHAs, such as rotary BHA, Rotary Steerable System (RSS) or Steerable Motor (SM), the drilling engineer needs modern software that should have the following requirements:

- Pre-engineering and post-analysis module
- Powerful 3D BHA-Drillstring / Hole interaction model

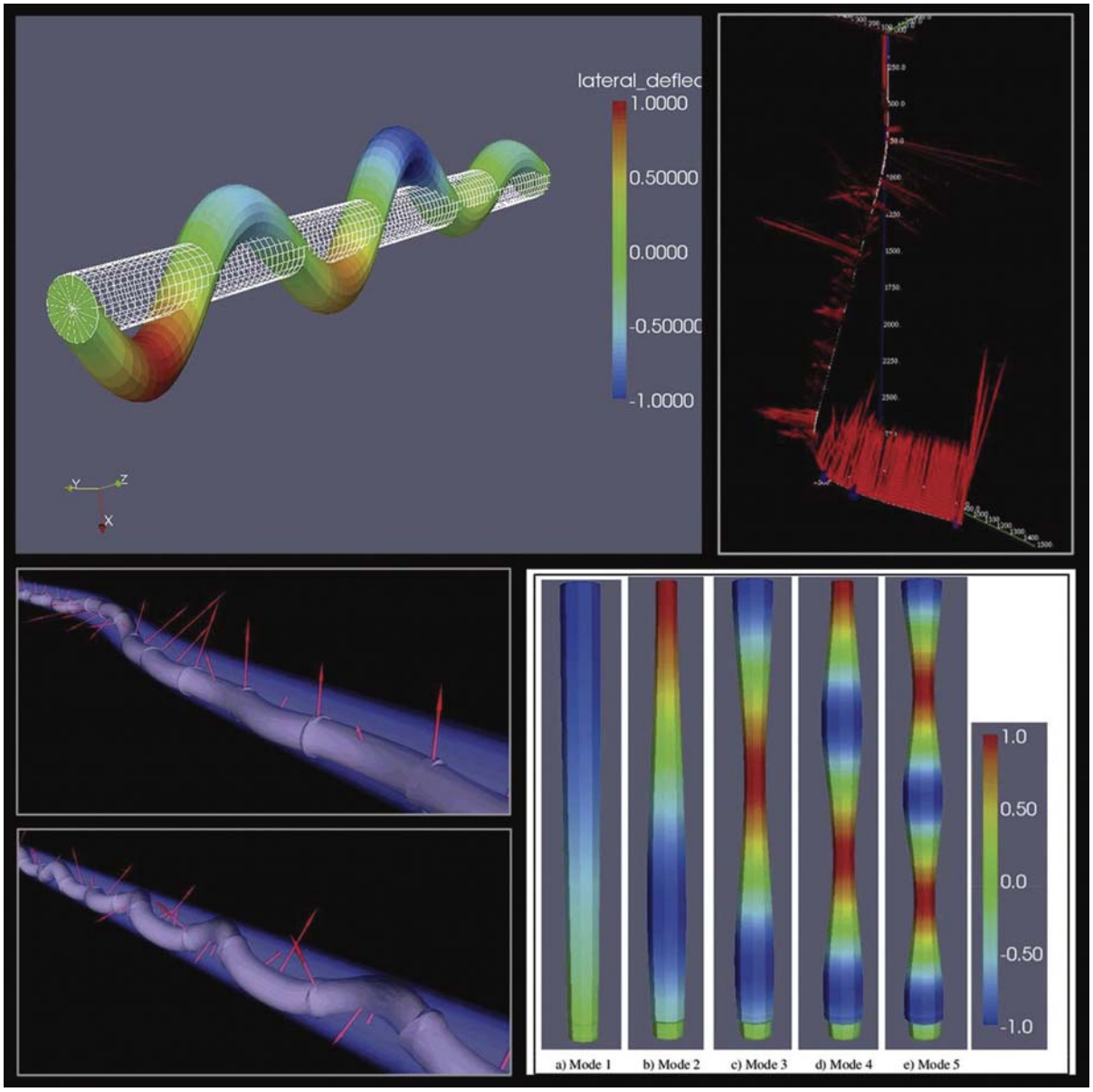

Figure 2: Torque, Drag, Buckling and Dynamics Simulations (BHA Management® software)

- Coupling between the drilling bit, BHA, and the rock formation to produce the directional response of the system

The pre-engineering module offers the possibility of quickly designing detailed directional BHAs of all types (Rotary, RSS or SM). This is done by selecting equipment in the database and running sensitivity analyses, to assess the potential, and validate the most fit-for-purpose design. An automated design process has also been implemented according to the Total expert operator's methods. The post-analysis module is designed to provide drillers with a simple tool to evaluate the BHA directional drilling performance achieved. Each run can be analysed to identify relevant BHA equilibrium curvature trends, and calibrate the fitting parameters.

The 3D BHA-Drillstring/Hole interaction model evaluates the BHA and drill string deflection, contact points and reactive forces in any kind of 3D curved borehole. It can simulate any directional system such as point-the-bit or push-the-bit RSS, SM, or Variable Gauge Stabilisers (VGS). No assumption is made about BHA-DrillString/Hole contact points, which are fully assessed by the model, using a powerful iterative process.

The bit model enables to fully characterise the bit's directional behaviour described through two main parameters: bit steerability and walk angle. Bit steerability corresponds to the ability of the bit, under lateral and axial forces, to initiate a lateral deviation. The walk angle corresponds to the angle between the lateral force applied at the bit by the BHA, and the direction of the bit's lateral displacement. The bit model introduced in the BHA Management® software includes a rock formation effect factor, clearly distinguishing unconsolidated sands, shales and limestones.

By coupling the BHA and the bit model, the software enables the computing of the equilibrium build/drop and turn rate of the

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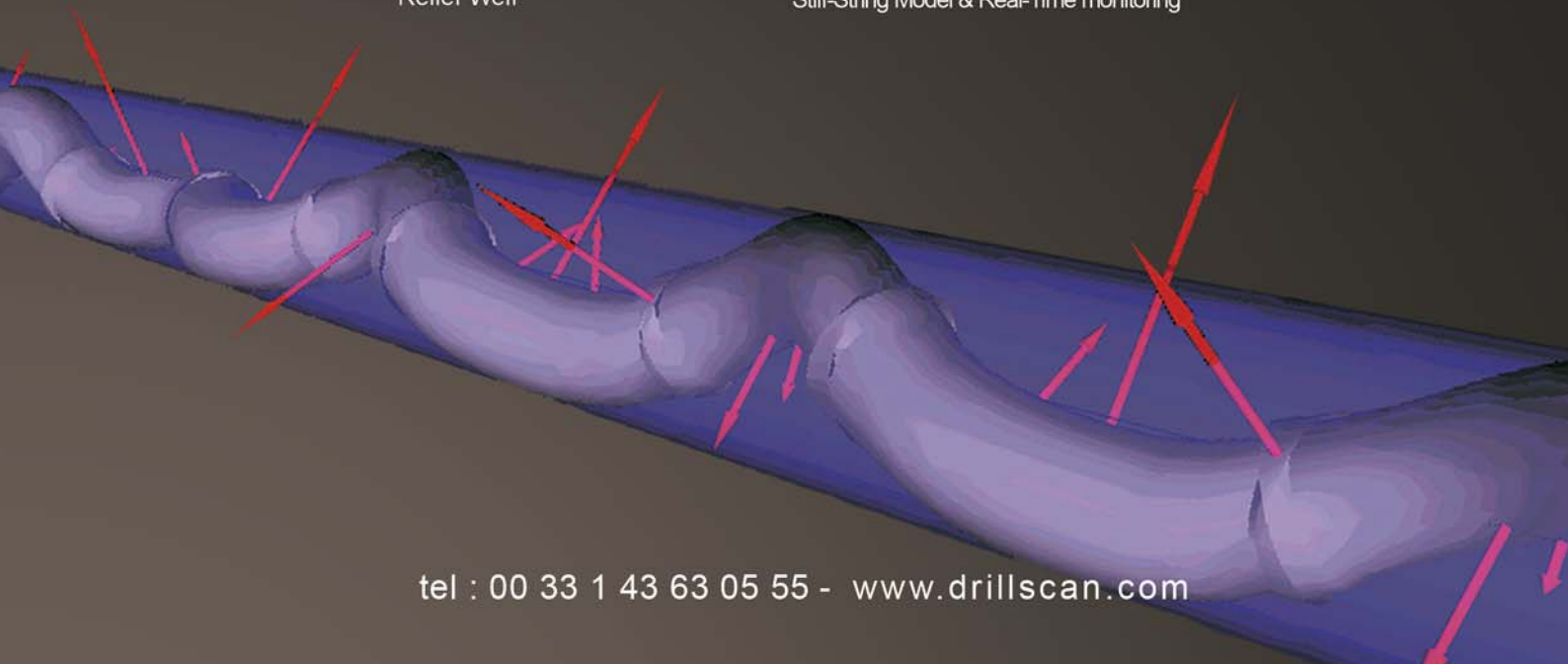

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directional system. Let's also notice that the model includes a step by step algorithm that estimates the local response of the directional system, which is of big concern regarding hole quality, such as hole spiralling, often encountered in deep vertical wells and interbedded formations.

Drilling vertical wells in hard formation for exploration is very challenging in terms of vibrations. BHA Management® software provides an evaluation of system natural frequencies and critical RPMs for any well geometry. The positions of contact points that play a major role in whirling frequencies are fully and accurately calculated with our 3D BHA/hole interaction model.

Offshore directional drilling requires also a strong focus on wellbore placement. Wellbore positioning uncertainties should be neither underestimated because of collision avoidance issues, nor overestimated in terms of target hitting. To address this issue, DrillScan has developed a new method based on the 3D BHA-Drillstring/Hole interaction model for BHA sag corrections and residual error evaluation at each survey stations. This solution has been applied on numerous case studies that have shown a significant well path re-positioning associated with a 50 per cent range improvement of the True Vertical Depth (TVD) uncertainty[1].

To date, the Total E and P affiliate has successfully deployed this new BHA Management® software on several wells, and achieved, in doing so, technical and economic performances far higher than expected[2].

TORQUE AND DRAG AND BUCKLING

The offshore well trajectories becoming very complex and challenging, the associated drill string composition being unconventional, and the material being used to its operating limit, the necessity to have a tool that realistically predicts forces, stresses, bending moment and contact loads along the wellbore is essential. Although the 3D mechanical behaviour of drill string is solved generally by using finite element analysis (FEA), the 3D BHA-Drillstring/Hole interaction model of the BHA Management® software is based on a new numerical method that enables to greatly reduce the computational time, while being as accurate and robust as FEA. For the first time, the software enables to simultaneously perform torque, drag and buckling, enabling taking into account in the friction analysis the increased contact force generated by the buckling.

The power of a 3D visualisation of the drill string deformed inside the wellbore enables easy localisation of contact loads

Thanks to this numerical breakthrough, the software can fully simulate the mechanical behaviour of a very long drill string in a 3D well trajectory within a few minutes (instead of hours with FEA), making real-time monitoring while drilling possible[3]. As no assumption is made on the localisation of the contact between the drill string and the borehole, the model more realistically predicts the side forces along the drill string, as can be seen in figure 2. This 3D stiff-string models takes into account the tubular stiffness, friction, rotation, temperature, hole size and clearance effects, and can handle the micro and macro tortuousness of actual well paths. The power of a 3D visualisation of the drill string deformed inside the wellbore enables easy localisation of contact loads on any drill string component, from the drilling bit (including side force at the bit and tilt) to the top drive or rotary table (hook load and rotary torque at surface), facilitating drilling problems analysis, as can be seen in figure 2.

FATIGUE

In the offshore high-cost and complex drilling environment, the importance of drill string failure and casing wear issue has dramatically reappeared, in spite of many manufacturing and materials improvements. Fatigue prediction is usually based on the cumulative fatigue damage model that requires an accurate calculation of the drill pipe stress caused by bending when rotated in a dog leg. The current practice is to assume that the curvature of the drill pipe is the same as the dog leg, leading to major under-estimation of the cumulative fatigue damage. Thanks to a better estimation of the stresses all along the drill string, BHA Management® software enables not only the estimation of cumulative fatigue damage on any drill pipe, but also to track any given equipment while drilling to minimise the risk of failures[4].

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Contact information

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