RESONANCE ENHANCED DRILLING

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Summary Resonance Enhanced Drilling (RED) is a novel oil and gas drilling technique being developed at the University of Aberdeen, which offers a significant increase of penetration rates. RED applies an adjustable high frequency dynamic stress from axial oscillations of a drill-bit. The oscillations are introduced behind the drill-bit by an actuator and the resonance conditions are maintained for by adjusting the frequency and amplitude to induce a steadily propagating fracture zone. In this paper, we present the full scale experimental rig and findings from the experimental studies which correlate well to our earlier theoretical predictions.

BACKGROUND, RED RIG AND EXPERIMENTAL STUDIES

Resonance Enhanced Drilling (RED), a novel oil and gas drilling technique, has been developed in the Centre for Applied Dynamics Research at the University of Aberdeen [1]. It offers a significant reduction of drilling cost by increasing penetration rates and reducing forces in a drill-string. The RED principle is based on inducing a controllable nonlinear resonance in a borehole by applying an adjustable high frequency dynamic stress generated by axial oscillations of a drill-bit, which works in combination with standard rotary drilling. The oscillations are introduced behind the drill-bit by an electro-mechanical actuator via a custom designed structural spring [2] and the resonance conditions between the drill-bit and the drilled formation are maintained for varying drilling conditions by adjusting the frequency and amplitude to produce a steadily propagating fracture zone. RED is particularly well suited for hard rocks for which penetration rates enhancement when compared to standard rotary drilling is large. From our mathematical modelling of the dynamic interactions (see for example [3,4]) and experimental studies on the RED experimental rig, it is clear that this improvement can quite often exceed 500%.

The main requirement in developing the RED experimental rig has been to reflect the physics observed in the downhole drilling process as close as possible. A conventional vertical drilling arrangement has been chosen for the experimental rig due to a number of practical reasons related to sensing and measurements. In our rig the drill-string is stationary and a rock sample is being rotated. The experimental setup to undertake drilling tests is shown in Figure 1, which details the main components and instrumentation. The experimental rig is made up of the fixed frame, the moving frame, the torque restraint frame, the vertical lathe, the hydraulic cylinder and the most important part, the drill-string. The drill-string is composed of the upper load-cell housing, the vibro-isolator, the back mass, the magneto-strictive actuator (PEX-30), the structural spring, the lower load cell housing, the drill-bit holder and the drill-bit.

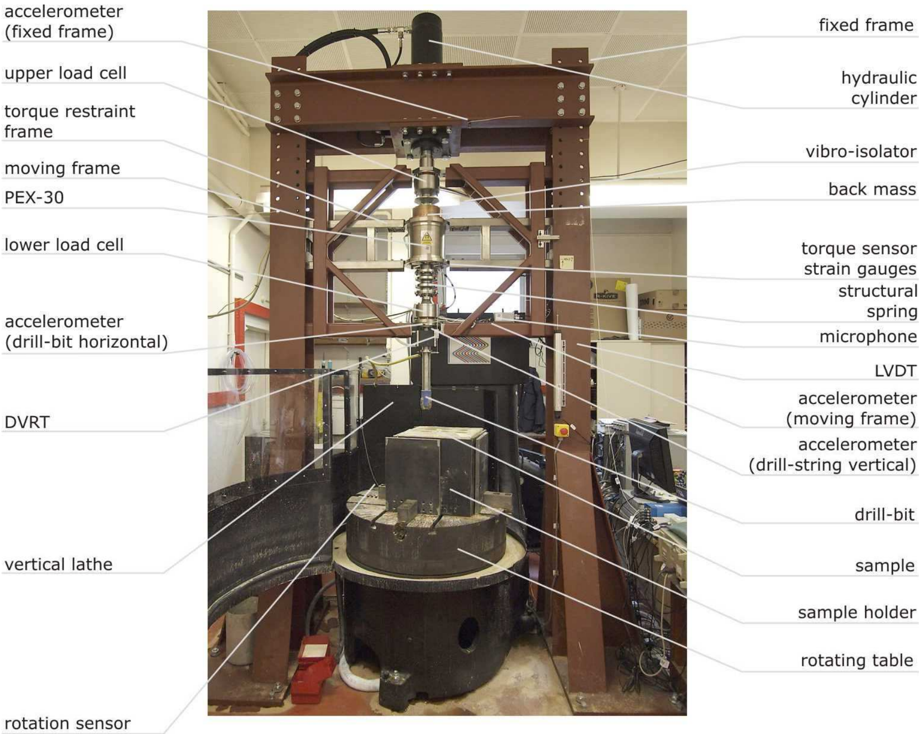

Figure 1: Experimental setup for RED tests developed by the University of Aberdeen

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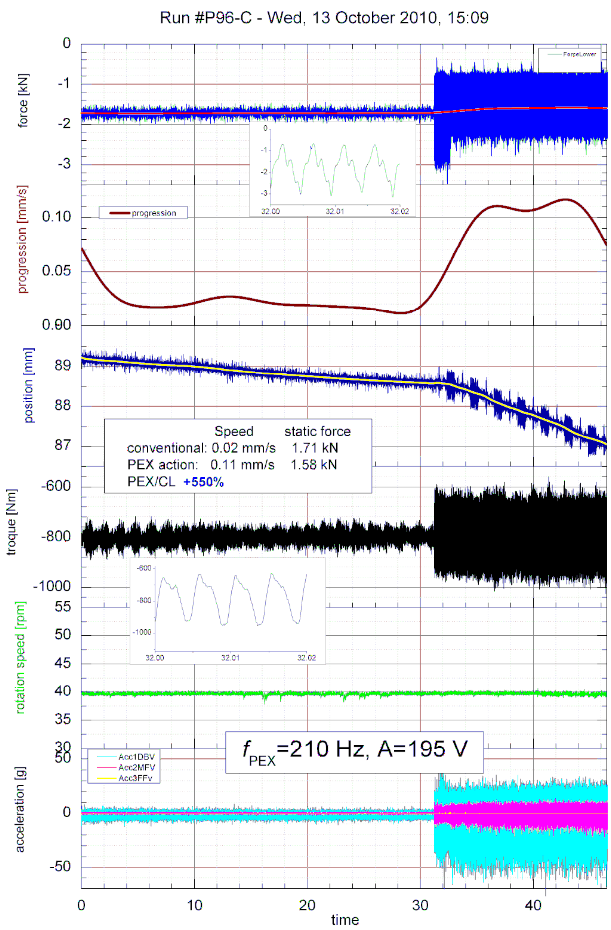

Figure 2: Experimental time histories for sandstone

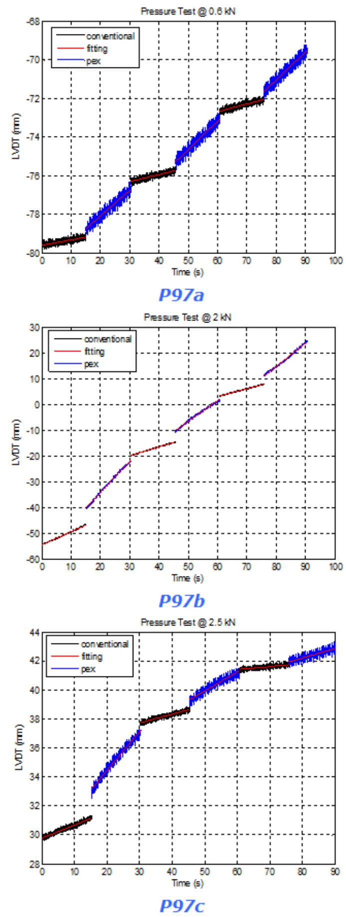

Figure 3: ROP for different WOB, 0.5, 2.0 and 2.5 kN

The experimental programme was designed to investigate the RED dynamics and Rates Of Penetration (ROP) enhancement for different types of rock samples and drilling parameters. It was anticipated that the control parameters, including Weight On Bit (WOB), rotary speed, drilling depth, excitation frequency and amplitude, would have a significant influence on the dynamics and ROP. The experiments were undertaken in four parts each testing the same type of rock such as sandstone, limestone, sandstone-quartz and granite. Figure 2 shows example experimental results, where a family of time histories of forces measured by the upper and lower load cell (see Figure 1), ROP, relative displacement, torque, rotational speed and accelerations on the drill-string, obtained for sandstone is depicted. Figure 3 compares the experimental ROPs obtained for the standard rotary (black) and RED (blue) drilling in 18 tests for three different WOB. It is clear that the best ROPs are in the medium WOB (middle panel), which correlates well with the theory and small scale experiments [4,3].

CONCLUSIONS

In this work Resonance Enhanced Drilling, a novel oil and gas drilling technique, has been presented. RED applies an adjustable high frequency dynamic stress generated by axial oscillations of a drill-bit in combination with standard rotary action. The oscillations are introduced behind the drill-bit by an actuator and the resonance conditions between the drill-bit and the drilled formation are maintained for varying drilling conditions by adjusting the frequency and amplitude to induce a steadily propagating fracture zone. We showed the full scale experimental rig and discussed sample experimental results.

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