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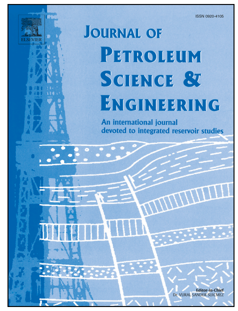

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From Shallow Horizontal Drilling to ERD Wells: How Scale affects Drillability and the Management of Drilling Incidents

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Abstract

The context of drilling operations is quite variable in geometric scale and complexity. Wells range from Extended Reach Drilling (ERD) wells with measured depths greater than 10km to exceptionally shallow wells no longer than 2 km but only 200-300 m in true vertical depth. With the objective of achieving greater levels of drilling automation, it is important to understand how the well geometrical scale impacts drillability and the management of drilling incidents.

The robust control of the drilling process necessitates the correct management of delays in the system. Some sources of delay are directly linked to physical dimensions, while others are the results of the system infrastructure. Time delays due to the travel of information through a medium belong to the first category while delays due to signal filtering or processing and actuator latency belong to the second category. The transient response of the drilling system greatly influences the controllability of the drilling process and both the detection and reaction times for drilling incidents such as over-pulls or pack-offs.

This paper proposes a categorization of the various sources of delay in a drilling system. A brief review of similar sources of delay in other industries is presented first, and then the sources of delay are characterized into four classes: the elasticity, inertia, and friction of the physical system, measurement refresh rate and latency, processing latency, and maximum actuator acceleration. Delays within these four classes are quantified for three different scenarios: a 10km-long ERD well, a shallow horizontal well, and a three-dimensional shale well. Illustrative examples of the four classes of delay are presented within these scenarios. Any drilling automation system faces a varying set of constraints for each application, which should influence both the automation procedures themselves as well as sensing requirements

The paper illustrates how scale influences the necessary constraints in drilling procedures, by comparing the delay within the full range of drilling scenarios. Human operator and rig system reaction time and variable awareness to drilling dysfunctions are the most limiting factors in improving drilling efficiency. The automation of drilling procedures with robustness considerations for scale and latency issues therefore plays an important role in increasing drilling performance.

Key words: drilling, scale, latency, drilling incidents

1. Introduction

The wellbore lengths, the drill-stem and borehole diameters, and the drilling fluid properties may vary by a factor of two to ten from one drilling operation to another. Therefore, the dominant mechanical and hydraulic effects can be completely different from one drilling condition to another one. With the objective of achieving greater levels of drilling automation, it is important to understand how scale impacts drillability and the management of drilling problems.

Control systems and drilling procedures are often tested on laboratory-scale rigs with dimensions rarely exceeding ten to 30m (see Junichi et al. 2015 for a few examples). Even full scale test rigs have limited dimensions, typically no longer than one to two kilometers (e.g., see the verification of a new drilling method on a test in Vestavik et al. 2009). For this reason, the full range of geometric scale, from one to ten kilometers, will be presented and then the effects of latency on drilling performance and drillability, both from the scale of the physical system itself and from the latency of the sensing and control systems, will be investigated.

The problem of working with variable scale is not unique to the drilling domain but there are few other industries that are confronted with so many sources of scale variability. Let us review how scale affects other technical areas.