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Trajectory Risk Index—An Engineering Method To Measure Risks of Multiple-Well Complex Trajectories

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Abstract

With the development of modern drilling technologies, the drilling industry has been pushing the envelope of well trajectory geometrical profile (such as ERD or horizontal wells) and the total number of wells possible from a single drilling location, such as an offshore platform or template. Risks involved in drilling these multiple "difficult" well trajectories have become significantly higher. The risks and difficulties are introduced by wellbore location uncertainty, accumulative wellbore friction, large horizontal step-out, high degree of change in inclination and azimuth, and complexity of well trajectory geometrical profile, etc.

There are many ways to place the wellbores for selected targets. However, risk and complexity in trajectory may vary greatly, and could be affected by many factors, such as collision risks, trajectory geometric shape, total measure depth and true vertical depth, change rate of inclination and azimuth, tortuosity, build up rate, and torque and drag. All these factors should be evaluated together during trajectory design. An engineering approach should be used to quantitatively measure the risk and complexity of each trajectory. Only then can the trajectories be optimized with potential for reduced operational risk and cost reduction.

This paper presents an engineering methodology and mathematical algorithms to quantify risks involved in different well trajectories, by calculating a Trajectory Risk Index (TRI). For the first time, the method combines collision risks, well geometry profile, tortuosity, and torque and drags factors in one simple measurable factor, to make a complex problem simpler. Applications of this engineering methodology are discussed with results for actual trajectory design data. The relationship of trajectory risk index and well cost is also identified and applications are discussed.

Introduction

After geologists and reservoir engineers identify drilling targets, it is the drilling engineers' job to design the wellbore trajectory for these targets. For the case of drilling multiple wells from a template drilling center, especially from an existing template or platform in a brown-field, there are many risks that need to be considered such as collision, trajectory geometric shape, true vertical depth and horizontal departure, inclination and azimuth, build-up-rate, tortuosity, and torque and drag. Risk level for each wellbore is different. Most of the time reservoir engineers would like to combine multiple targets into one trajectory to save drilling cost, and this will often require the well trajectory to change in both inclination and azimuth. If nearby wells are close to each other, such as drilling from a platform, collision risk will most likely be high; potentially requiring a trajectory designed to build and turn, sometimes aggressively, at shallow depth to avoid collision. On the other hand, even when a trajectory is safe from collision under normal designed operating conditions, any tool failure or human error could increase the ellipse of uncertainty and increase collision risk. When designing a well trajectory, all risks and sensitivities of the risks should be estimated, and trajectory design should be optimized accordingly. After wells are drilled, evaluation and benchmarking drilling performance is also important for learning and future design and operations. Drilling engineers need an engineered approach to quantify the risks for trajectory optimization and post drilling evaluation.

Some work has been done on benchmarking and evaluating drilling operation performance[1-5], but there is no effective engineering methodology to quantify and measure all risks mentioned above together for both well trajectory design and after drilling evaluation, and none of the earlier works has considered collision risk, which is one of the most important risk factors in multiple well design. This paper develops an engineering approach to quantitatively measuring drilling risks of each well trajectory by using Trajectory Risk Index (TRI). It will also demonstrate that TRI is directly related to well cost.

Total Trajectory Risk Index Calculation

To provide a comprehensive quantitative risk measurement for a well trajectory, all factors discussed above are studied, and measurements of all risks are developed. The approach proposed in this paper uses two methodologies: a geometrical mathematical model is used to calculate Trajectory Difficulty