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A New Buckling Severity Index to Quantify Failure and Lock-up Risks in Highly Deviated Wells

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Abstract

Buckling of tubulars inside wellbore has been the subject of many researches and articles in the past. Evidences in the laboratory and in the field have shown that existing buckling criteria (sinusoidal and helical buckling) have to be challenged, as they fail to predict the onset of buckling phenomenon in complex or unconventional wells drilled today. Indeed, existing buckling criteria assume generally that the wellbore is idealistically perfect without any dog legs. Recent advancements in drillstring mechanics modelling has demonstrated that dog legs, friction and rotation affect greatly the buckling phenomenon. Buckling does not imply necessarily failure neither lock-up, but indicates the onset of a condition that may generate poor drilling performance that could lead to failure or lock-up. In this paper, one proposes a new buckling severity index that quantifies the severity of the buckling phenomenon enabling drilling engineers to take appropriate decision.

A fully validated numerical buckling model has been used to derive a new buckling severity index based on the risk of drill pipe failure or lock-up. This index ranges from 1 for acceptable buckling condition with low risk of failure, to index 4 for severe buckling with high risk of failure or lock-up. This new buckling severity index has been compared to well-known sinusoidal and helical buckling loads in a few case studies, and demonstrates that past buckling criteria should be used very cautiously.

This paper proposes an update of past conventional buckling criteria in recommending a new buckling severity index that enables to quantify the risks of failure or lock-up in unconventional and deviated wells. These new results presented in this paper should improve significantly well planning and operational procedures to drill and operate increasing complex wells.

Introduction

The general definition of buckling is “A state of unstable equilibrium of a thin-walled body when compressive loads are applied on its walls. The resultant deformation may be elastic or permanent. In some cases, it may even lead to collapse of the structure” [source: McGraw-Hill Dictionary of Aviation]. The most important words in this definition are certainly “unstable equilibrium” and “compressive loads”. In the drilling industry, buckling occurs when the compressive load in a tubular exceeds a critical value, beyond which the tubular is no longer stable and deforms into a sinusoidal or helical shape (constrained buckling), corresponding to two particular unstable equilibirums. It is worth noting here that these two last special shapes are a particular case for a given situation, as the shape of the buckled drill pipe may take other forms[1,2,3] depending on the hole geometry. The sinusoidal buckling (first mode of buckling) corresponds to a tube that snaps into a sinusoidal shape. This first mode of buckling is sometimes called lateral buckling, snaking or two-dimensional buckling. The helical buckling (second mode of buckling) corresponds to a tube that snaps into a helical shape (spiral shape). The first work dedicated to the buckling behavior of pipes in oil well operation was initiated by Lubinski[4,5]. Since then, many theoretical works and/or experimental studies[1-12] have been developed to better understand and model the buckling phenomenon, and to take into account the effects due to wellbore geometry, dog leg severity, torque/torsion, tool-joint, friction and rotation.