



IADC/SPE 112571

How Drillstring Rotation Affects Critical Buckling Load ?

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This paper was prepared for presentation at the 2008 IADC/SPE Drilling Conference held in Orlando, Florida, U.S.A., 4–6 March 2008.

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Abstract

Buckling of tubulars inside wellbores has been the subject of many researches and articles in the past. However, these conservative theories have always followed the same assumptions: the wellbore has a perfect and unrealistic geometry (vertical, horizontal, deviated, curved), the friction and rotation effects are ignored, conditions relatively far from actual field conditions. How do tubulars buckle in actual field conditions, that is, in a naturally tortuous wellbore with friction and rotation? Can we apply theories developed for perfect well conditions (no tortuosity, no friction, no rotation) to actual well conditions?

For the first time, this paper presents how the drillstring rotation affects the critical buckling load in actual field conditions. These new results have been obtained from an advanced model dedicated to drillstring mechanics successfully validated with laboratory tests.

Firstly, this paper presents the new developments integrated in a recently advanced model for drillstring mechanics that enables to take into account the buckling phenomenon in any actual well trajectory. Indeed, some simultaneous torque-drag-buckling calculations are presented and allow to properly take into account the additional contact force generated in a post-buckling configuration, and as a consequence the additional torque at surface. Secondly, this paper shows the influence of friction and rotation on buckling loads for some practical and critical cases met in the drilling industry. These friction and rotation effects are demonstrated with an experimental set up that enables to confirm theoretical features. Lastly, this paper shows that using standard

buckling criteria may lead to too conservative solutions, and that under specific circumstances, the drilling and completion engineer could safely operate in a buckling mode for a given time.

These new results presented in this paper should improve significantly well planning and operational procedures to drill and operate more and more complex wells.

State of the Art

Introduction

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. 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^{1,2}. Since then, many theoretical works and/or experimental studies have been developed to better understand the buckling phenomenon. The aim of the following sections is to present the different improvements made in buckling analysis to take into account the effects due to wellbore geometry, torque/torsion, tool-joint, friction and rotation. This section will show that each study has been done in analyzing each effect independently of the others, and as a consequence cannot completely address buckling issue.

Effect of Wellbore Geometry

First theories were developed for perfect vertical wellbores without friction by Lubinski¹. Then, the buckling behavior of drill pipes in inclined wellbores was first proposed by Dawson & Paslay³, based on earlier work by Paslay & Bogy⁴. The authors came to the following known critical buckling load for sinusoidal mode :

$$F_{sin} = 2 \sqrt{\frac{EI \omega \sin(Inc)}{r}} \quad (1)$$