Mechanical Analysis of Subsea Wellhead in Deepwater Wells  
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ABSTRACT

To maintain the stability of subsea wellheads, the complex wellhead loads need to be analyzed. A mechanical method is proposed to calculate these wellhead loads during wellhead installation and well production. Case studies show that wellhead sinking can occur during the process of cementing the surface casing because of the significant downward wellhead load and an improperly adjusted hook load. During production, wellhead growth may occur if the upward load is so large that the conductor moves with the wellhead as a whole. Finally, mitigation methods are proposed and summarized to alleviate wellhead sinking and growth.

KEY WORDS: Pressure; Casing; Temperature; Wellhead sinking; Wellhead growth; Wellhead stability; Wellbore integrity.

INTRODUCTION

A multitude of deepwater wells have been drilled around the world in recent years to explore and develop oil and gas resources in the ocean. However, subsea wellheads in deepwater wells are typically threatened by complex loads, which may result in wellhead movement (Sathuvalli and Suryanarayana, 2016). Many subsea wellhead accidents, such as wellhead sinking, have been reported in deepwater wells, leading to the destruction of the wellbore integrity. In addition, during oil or gas production, deepwater wells continuously face significant temperature changes attributable to the heat produced by the production fluid; as a consequence, wellhead growth, which is a common phenomenon in HTHP (high-temperature and high-pressure) wells, may occur (Liang, 2012). To predict and prevent these risks, it is necessary to understand the mechanical behaviors of subsea wellheads.

A subsea wellhead is an important component that is placed at the mud line. Some scholars have studied the loads and stability of subsea wellheads; for example, Su (2009) analyzed the mechanical behaviors of risers and subsea wellheads. Methods have been established to calculate the bending moment, axial force and lateral force on the wellhead. Guan (2010) analyzed the wellhead stability by considering the environmental loading, the mechanical behavior of the riser and the drifting of drilling vessels, among other phenomena. Wang, Gao and Hu (2018) studied subsea wellhead growth by analyzing the thermal loads that appear during the production process. Tian (2017) investigated the subsea wellhead stability while considering sand liquefaction and summarized various useful conclusions with regard to maintaining the wellhead stability. Wang, Gao and Fang (2018) studied the subsea wellhead stability by discussing the bearing capacity of conductors. Chang (2017) estimated the dynamic loading of subsea wellheads and examined the fatigue of the wellhead. Nevertheless, the abovementioned studies did not reveal the mechanical behavior of a subsea wellhead throughout the life cycle of a deepwater well, including the load variation during the wellhead installation and production processes. During the life cycle of a deepwater well, the loads on the subsea wellhead are complex and variable; as a result, the wellhead can exhibit severe instability. Therefore, a method should be established to calculate the load on the wellhead during deepwater construction and production processes.

This paper analyzes the mechanical behavior of a wellhead from the following perspectives. First, the loads on subsea wellheads are calculated, and wellhead sinking is analyzed by examining field cases. Then, the wellhead loads during the production process are calculated. Finally, the potential for wellhead growth in deepwater wells is discussed.

MECHANICAL ANALYSIS OF SUBSEA WELLHEADS

Installation of a subsea wellhead

Prior to analyzing the loads on subsea wellheads, the procedure with which a subsea wellhead is installed should first be discussed. A schematic of a subsea wellhead is presented in Fig. 1. The wellhead consists of both a HP (high-pressure) housing and a LP (low-pressure) housing. The conductor is connected to the base of the LP housing. The surface casing, technical casing, production casing and tubing are hung on the HP housing, and the HP housing rests on the LP housing to form an intact subsea wellhead.