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Frade Field Dynamic Umbilicals Design and Testing

Bradley Clarkston, Chevron USA; Ernesto Valenzuela, EV Consulting, Inc.; and Peter Worman and Paul Williams, Oceaneering International, Inc.

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Abstract

Frade umbilicals were designed using a dynamic Free-Hanging Catenary (FHC) configuration based on a risk-based approach instead of a prescriptive rules approach. Innovative designs falling outside the normal scope of classification are sometimes difficult or even impossible to get through a normal approval process based on prescriptive rules, such as API 17E and ISO13628-5 standards. Furthermore, the utilization of prescriptive rules would have led to a "wavy-wave" configuration (WWC), which utilizes buoyancy modules closer to the touch down point of the umbilical to reduce compression on the seabed. The FHC configuration is much affected by the heave of the vessel, which induces a compressive wave that travels back up the umbilical from the touchdown point. Because of the low tension of the umbilical on the seabed, compression in deep water becomes an important parameter; therefore, the significance of the subject matter for designing a FHC configuration in deep water is to properly assess compression on the seabed, which may cause excessive plastic strain in the tubing, or failure in the quad electrical cable. Common industry practice has been not to accept compression. Therefore, testing was used to better understand and to ascertain a safe level of compression that could be used for the Frade design. The main conclusion after testing umbilicals under compression is that they do not follow the behavior of a rigid strut but instead they follow the behavior of a coiled spring because of its helix design up to an axial displacement of 450 mils.

To be able to assess non-linear stresses in the tubing, the risk-based approach used a bending moment factor technique and a gradient factor technique to estimate fatigue life. These techniques proved to be efficient tools for demonstrating feasibility of the FHC as well as for planning for spares if failures do occur during the 100-year storm. Therefore, the final conclusion was that the two type umbilicals, production and water injection were technically acceptable using a FHC configuration.

Introduction

Compression on the seabed induced by the vessel heave is the main parameter that makes feasible an umbilical design in deep water using steel tubing, and it is often found in umbilical configurations particularly with free-hanging catenaries. This is because the umbilical is massively axially stiff in comparison to its bend stiffness. As the umbilical is "speared" into the seabed by the action of the FPSO heave motion above it tends to induce local buckling, and one of the manifestations is a kink effect followed by a bird-caging effect or armour "lifting", which could lead to displacement of armour wires and a weakening of the bundle strength. API Specification 17E and ISO-13628-5 standards do not provide specific guidance for levels of compression, nor how it develops and its consequences. Therefore, as a solution Chevron carried out compression tests to better understand the umbilical behavior, as well as to ascertain a safe level of acceptable compression for the Frade design.

The Frade Field

The Frade Field as presented in Figure 1 is located in 1100-1250 meters of water approximately 120 kilometers off the coast of Brazil in the prolific Campos Basin. The FPSO is moored in a water depth of 1,065 meters. The field was discovered in 1986 by Petrobras and was subsequently appraised with a Petrobras well in 1989 and two Texaco wells in