Well intervention stack safety and equipment selection for offshore/onshore operations: use of longer, higher pressure stacks for well interventions prompted design and successful application of a stress modeling and field operation monitoring system

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The following article introduces the Zeta Safety System developed by CTES with support from BP. The new system, comprising two primary components, the Zeta Model and the Zeta Gauge, allows the operator to design safer well intervention stacks and monitor stresses on the stack during intervention operations. Following an introduction and background, the article describes: 1) failure modes; 2) the Zeta Model and Zeta Gauge; 3) a user's perspective; 4) field results of several applications; and 5) project status and future plans.

INTRODUCTION

Well interventions with coiled tubing, snubbing, slickline or wireline are becoming more challenging due to increased well complexity, more sophisticated applications, higher wellhead pressures, deeper wells, and floating structures with independently moving wellheads. These challenges often require taller, higher pressure intervention stacks with less stability than classic stacks. These conditions can impart significantly increased stress levels on the well intervention stack.

Based on observations of wave-induced equipment movement during well operations on floating platforms, the staff at BP recognized the need for a tool that would allow intervention stack stress to be modeled and/or measured in real time. BP brought this need to CTES, and after several brainstorming sessions, the Zeta Safety System project emerged.

Anecdotal evidence indicates that four or rive catastrophic stack failures occur each year. Many more "near miss" events occur, in which some component of the intervention stack is bent but does not fail. Stack failures result in additional costs due to unproductive time. Failures also provide a situation that could involve human injury and unplanned well pressure release.

Historically, there has been a lack of tools to accurately model and monitor these intervention stacks. Swaying of the stack can often be observed as a result of wellhead, or floating platform movement. Stack movement is routinely observed on risers supported by a crane, due to the limited lateral support provided by the crane and guy wires. Knowing how much sway is within sale operating limits, when more supports are needed, when to halt operations due to safety concerns as a result of changing job conditions, and selection of the proper intervention equipment has depended on experience of personnel responsible for the field operation.

The Zeta Safety System utilizes data and modeling to eliminate guesswork commonly associated with well intervention stack design and operations. The system contains two primary components: 1) Zeta Model--a purpose written dynamic finite-element model which calculates deflections and stresses along the entire stack; and 2) Zeta Gauge--a short instrumented lubricator section which uses state-of-the-art fiber-optic technology to accurately measure axial-force, bending moment and internal pressure at a specific location in the stack.

The Zeta Model is used in the job design phase to model the intervention stack and determine the proper equipment and support structure required to safely perform the field operation. For example, the model can determine if a gimble table or some other type of displacement compensation system is required. It also determines buckling load and point of maximum stress in the stack.

The Zeta Gauge is ideally placed near the maximum stress point. During the intervention, it monitors actual bending moments, axial forces and pressures, and calculates resulting stresses. If these stresses exceed sale working limits, the system warns the operator.

FAILURE MODES

There are basically two ways an intervention stack can fall: buckling and bending.

Buckling. This occurs due to structural instability. A long slender column will fail when a compressive "buckling load" is applied. The classical method of calculating this buckling load is known as the Euler buckling calculation. There are models in the industry that use Euler buckling to try to determine if an intervention stack is sale. However, there are several problems with this technique:

* A "K" factor is required for the Euler calculation, which is dependent on column end conditions. Real-world intervention stacks often have more complicated end conditions than those provided for with theoretical Euler buckling. Often, the K factor is misapplied. Fortunately, the error is usually on the side of caution.

* The Euler models apply to a straight, constant diameter, weightless column. An intervention stack has large BOPs, small lubricators, larger valves, all of which are far from weightless! As a result, predicted critical buckling loads from the Euler model are higher than actual buckling loads. This can lead to a catastrophic buckling failure during field operations.

* These Euler models cannot address complex loading conditions and supports round in a typical intervention stack. Side loads such as coiled tubing reel back tension, bending moments applied by off-center loads, guy wire or chain supports attached at various locations along the stack, and the bending and dynamics of moving wellheads and platforms (SPARs and TLPs) cannot be considered in these models.