

Analysis of Casing Deformations in Thermal Wells

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Abstract: Thermal technologies are widely used for the heavy oil recovery. The thermal processes usually consist of some variation of Cyclic Steam Stimulation (CSS), steam flood or Steam Assisted Gravity Drainage (SAGD). These thermal recovery applications have experienced numerous well casing failures around the world, often resulting in loss of wellbore integrity, lost production and added costs. The primary casing failure mechanisms include casing connection leakage and/or parting due to excessive casing strain and wellbore serviceability difficulties due to large casing deformation associated with casing buckling and shear.

Due to high operation temperatures (e.g. 220 to 350°C), casing deformations often exceed the elastic limit of typical thermal well casing materials. Therefore, a strain-based design concept and advanced finite element analysis are often used to consider the allowable casing strain capacity beyond yield and the associated non-linear material and structural responses. This paper presents analysis models, developed using Abaqus, for analyzing casing deformations resulting from thermal loading, buckling and formation shear movement. It is demonstrated that the analysis results of casing deformations can constitute a more advanced and sound basis for thermal well casing designs which minimize the potential for thermal wellbore casing failures.

Keywords: Casing, Connection, Thermal Well, Thermal Cycle Loading, Buckling, Formation Shear, Plasticity, Strain-based Design, Axisymmetric-Asymmetric Elements, Beam Elements, Slide-line Contact Elements, Pipe-in-Pipe Contact Elements

1. Introduction

Thermal technologies are widely used for heavy oil recovery worldwide. The thermal recovery of viscous heavy oil and bitumen is often achieved by some variation of Cyclic Steam Stimulation (CSS), steam flood or Steam Assisted Gravity Drainage (SAGD). A thermal cycle in CSS consists of four basic phases: high pressure, high temperature steam injection; a soak period, where the well is shut-in to allow for the injected steam to penetrate the reservoir and decrease the oil viscosity; flow-back, where the elevated reservoir pressure is sufficient to produce the hot oil, condensed steam and gases to surface; and pumping to lift the produced fluids to surface as the reservoir cools. SAGD is a more stable, gentle process where steam is continuously injected into one horizontal well, and condensed steam and mobilized fluids are produced from a second well (Xie, 2000). This method usually requires lower injection pressures and temperatures and fewer pressure/temperature cycles than CSS. The CSS process has been applied to a variety of well configurations including vertical, directional and horizontal as shown in Figure 1. SAGD applications are typically limited to pairs of parallel horizontal wells with the dedicated injector situated just above the dedicated producing well (Figure 2).