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Subsea Pipeline Behavior Under Seismic Impact

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ABSTRACT

A new analytical approach to determine the effect of unburied pipeline under seismic faults is presented in this paper. This study investigates an unburied offshore "snaked" pipeline behavior under various types of seismic ground-slip faults. The snaking of the pipeline is caused by the thermal/pressure expansion and soil friction forces. The snaking takes place at a certain distance from the pipeline unrestrained end and gradually increases towards the restraint. It is shown that seismic faults have less effect on straight than snaked pipeline. The new seismic design demonstrates that an order increase in seismic magnitude (a large increase in ground displacement) causes very small change in unburied pipeline bending and total longitudinal stresses. The new approach has been applied in practice to achieve safe, subsea pipeline construction and operation with a significant cost reduction.

KEY WORDS: Pipeline, seismic slip fault, lateral deviation/snaking, pipeline expansion.

INTRODUCTION

Modern subsea pipeline construction assimilates the new fields of development which often propagates to seismic active zones. These offshore zones include south-east and far-east Asia, west and west-north America. The new fields located in regions with high probability of earthquakes have a potential hazard on offshore pipeline operational stability and integrity. Pipeline seismic hazard analyses require an assessment of the future earthquake potential, type of faulting (slip type), and an estimate of soil displacements. This database determines the unburied pipeline resulting movement, deformation, and strains imposed by a seismic fault.

Nyman (1972) presented comprehensive classifications of the ground faults as being either strike-slip, normal-slip, or reversed-slip, depending on the predominant component of movement. Wells and Coppersmith (1994) addressed technical issues involved in regressional analyses of the empirical relationships between earthquake magnitude and soil displacement/soil foundation rupture width and length. The results of that study empirically correlated seismic seabed displacement with earthquake magnitude (at a 95% significance level). Dunlap et al (1990) presented the cyclic load test results and an estimate of pipeline embedment in weak sediment under vertical loading. Behavior of a buried pipeline under large ground slip imposed by the structure vertical displacements was investigated by Zhilong and Murray (1993). The pipeline was represented as a sequence of straight beam finite elements supported on the bottom by bearing soil springs and on the top by uplift soil springs. The local buckling, wrinkling and conditions of surrounding soil were found to have great influences on pipelines behavior. Rajani et al (1993) studied a buried pipeline transverse movements due to displacement in the ground caused by landslides similar to a seismic strike slip-fault form of movement. The known soil resistance non-linear model (elasto-plastic soil) was used in their analysis. Pipeline maximum bending moment versus soil lateral displacement relationship was determined. Trigg and Rizkalla (1994) studied buried pipeline behavior into unstable slope. The soil movements were considered to be in both transverse and longitudinal directions. The closed form solutions were developed for a pipeline subjected to lateral and longitudinal displacements. However, the developed models deal with the pipe's tensile rupture failure modes and cannot treat the buckling failure mode. The dynamic aspect of a buried offshore pipeline seismic stability was considered by Figarov and Kamyshev (1996). The seabed vibrations through the pipeline surrounded soil transfers the dynamic loads. Figarov and Kamyshev have shown that the maximum dynamic effect of the pipelines is experienced with longitudinal directions of the seismic wave shock which induces pipeline vibrations. The possibility of pipeline resonance phenomenon was indicated.

Ju and Kyriakides (1988), Hobbs (1984), and Kershenbaum et al (1996) have shown that both offshore and onshore pipelines