

Pipe-Soil Interaction Behavior During Lateral Buckling, Including Large Amplitude Cyclic Displacement Tests by the Safebuck JIP

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Abstract

This paper addresses lateral pipe-soil interaction behaviour at the large displacements that occur with lateral buckling of a pipeline. Force-displacement response models were developed by the SAFEBUGK JIP to replace the use of Coulomb friction approximations, which are unrealistic for the large lateral displacements that occur upon buckle formation and inappropriate for modelling the development of soil-berms that occur with lateral cyclic displacements in operation.

The models are based on large and small-scale tests, carried out by the SAFEBUGK JIP on deepwater soils from the Gulf of Mexico and West Africa, as well as kaolin clay. To this database was added project specific test data donated by JIP participants.

Four stages of pipe-soil interaction are considered:

- Embedment of the pipe at installation
- Break-out, during buckle formation based on different levels of initial pipe embedment;
- Large amplitude displacement as the buckle forms;
- Repeated cyclic behaviour, influenced by the building of soil berms.

While breakout loads have been the subject of much research and published papers on pipeline stability, there is little guidance on modelling lateral resistance at the large displacements experienced in lateral buckling. There is also little guidance on modelling subsequent large amplitude cyclic behaviour, which occurs with each shutdown and restart of the pipeline.

The models provide an important basis for lateral buckling design guidance; they are being applied by JIP Participants on a number of current projects where pipelines are being designed for lateral buckling.

Background to the SAFEBUGK JIP

The aim of the SAFEBUGK JIP is to raise confidence in the lateral buckling design approach and improve understanding of the related phenomenon of pipeline walking; with experimental work at TWI on low cycle fatigue materials performance, and at Cambridge University on axial and lateral pipe-soil interaction.

The scope of work for the SAFEBUGK JIP is summarised^[1] in Figure 1, which highlights the key parts of the lateral pipe-soil interaction scope of work covered in this paper.

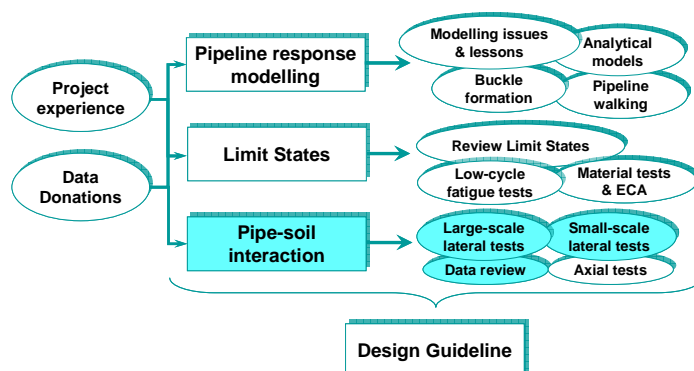


Figure 1 - Scope of work for the SAFEBUGK JIP

Introduction

Subsea pipelines are increasingly being required to operate at higher temperatures and pressures. The natural tendency of a pipeline is to relieve the resulting high axial stress in the pipe-wall by buckling. Such uncontrolled buckling can have serious consequences for the integrity of a pipeline. Consequently, the industry has generally sought to restrain pipelines by trenching, burying and rock-dumping; or relieving the stress with in-line expansion spoos.

A far more elegant and cost-effective solution is to work *with* rather than *against* the pipeline by controlling the formation of lateral buckles along the pipeline. Controlled lateral buckling is an efficient solution to the relief of axial compression. Indeed, as operating temperatures and pressures increase further, lateral buckling may be the only economic solution. With the increase in deepwater developments, where pipeline trenching is uncommon, even low temperature