Operational Through-life Pipe Soil Interaction Modelling

Emil A. Maschner, Shulong Liu, Yunxiao N. Wang
Wood PLC. (London), UK.

ABSTRACT

Detail pipe soil testing and back analysis investigations of operational pipelines sited on different soil types and seabed terrains has identified time and cyclic displacement varying axial and lateral soil restraint mechanisms. These cyclic Pipe Soil Interaction (PSI) mechanisms have been shown to have significant impact on the through-life displacement response of operational pipelines. The inclusion of cyclically varying PSI input parameters into 3D global buckling and pipe walking models via appropriate Finite Element (FE) sub-routines, have been qualitatively verified on Wood Group projects and enable realistic assessments of pipeline integrity and through-life operational risk.

This paper describes the impact of pipe soil modelling issues on operational pipeline responses and the detail axial, lateral and 3D pipe soil sub-routines developed in-house to capture their global behavior within cyclic FE simulations.

KEY WORDS: Pipeline; soil; interaction; cyclic; displacement; simulation; design.

INTRODUCTION

For certain soil types, particularly soft cohesive sediments which allow significant levels of pipe embedment and consolidation with time, the adoption of simple bi-linear first load equivalent axial and lateral friction curves to represent the through-life soil restraint can lead to significant inaccuracies compared to the observed displacement response of operational High Pressure / High Temperature (HT/HP) pipelines. In complex pipe buckling and walking analyses, previously ignored aspects such as seabed undulation, nature of pipelay, operation startup/shutdown frequency and the extent of axial and lateral cyclic displacement levels have all been found to significantly change levels of soil restraint.

In addition, recent optimal designs have shown a requirement to include detail analysis of ‘through-life’ soil berm and axial restraint increases for transportable non-cohesive sediments or cemented calcareous sands.

To enable optimized cost effective and robust design schemes pipe soil interaction data from specialist geotechnical consultancies has become increasingly complex. This presents a challenge to pipeline design consultancies regarding how to include additional non-linearity and through-life cyclically varying input data within their FE modelling.

Compounding the design engineer’s problem is the need to develop buckling, walking and spanning mitigation schemes in project time frames. This often necessitates an initial rationalization of the Geotechnical inputs and modelling approach as a requirement of undertaking numerous pipeline response sensitivity studies along long route lengths.

This paper presents details of Pipe Soil Interaction FE sub-routines developed for operational back analyses and detail design use on Wood plc projects. It should be noted that the geotechnical aspect of pipe soil interaction is not the subject of this paper which is discussed elsewhere by others, e.g. Bruton et al. (2009), White et al. (2015), Cheuk et al. (2017) and Low et al. (2017). Among the benefits and understanding obtained from advanced PSI modelling are:

- Realistic through-life heat-up/cooldown effective force profiles
- Reliable and cost-effective design of planned buckle schemes and their effective force control
- Avoidance of unnecessary pipeline walking evaluations and mitigation
- Consideration of bend and planned buckle stability from operational pull out forces
- Optimal end expansion and spool sizing
- Optimized pipeline anchoring schemes
- Reduced through life inspection frequency as part of the overall Integrity Management Scheme

Axial Friction

Typically, in pipeline design analyses the equivalent axial friction input has been assumed to be bi-linear. Whilst acceptable in many cases, recent soft soil projects have highlighted a significant (if uncertain) contribution from an initial peak component. DNVGL-RP-F114 (2018) and SAFEBUCK III guideline (2015) advises on the extent and of the axial peak in terms of its mobilization distance. Figure 1 shows a tri-linear...