Structural Modelling of Multi-Span Pipe Configurations
SubJECTED TO Vortex Induced Vibrations

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ABSTRACT

The purpose of this paper is to discuss the method for describing the dynamic structural response of a pipeline under vortex-induced vibration. Both the conventional single span model with simple boundary conditions, and a three-dimensional multispam model representing a pipeline on an uneven seabed are considered. Particular attention is given to the sensitivity to variables affecting the predicted span behaviour such as end conditions, effective force, soil-pipe interface and span interaction. Comparison between single span and multispam results reveal that the single span analysis method is not always conservative and the natural frequency is as dependent on effective force and axial restraint as it is on span length.

KEY WORDS: Pipeline, modal analysis, vortex shedding, single span, multispam, span interaction, 3D FEM.

INTRODUCTION

Free-spans will be present when pipelines are installed on an uneven seabed or will develop by erosion of the supporting seabed, see fig. 1a. If the pipeline is exposed to wave or current forces the unsupported pipe span is susceptible to vortex induced vibrations (VIV). As the dynamic excitations of the free-span may cause fatigue damage at the welds, it is important to be able to identify spans that need to be corrected through seabed intervention. This assessment is an important part of pipeline design.

The VIV assessment basically consists of two components; a hydrodynamic part and a structural response part. VIV occurs when the hydrodynamic excitation frequency is within a certain range that coincides with the natural frequency of the span. The phenomena of fluid flow past a solid body causing VIV is of relevance to many engineering applications. The fluid dynamic mechanism causing VIV have been extensively researched and documented. Comprehensive overviews of pipeline VIV methodology and experiments are given by Sumer (1994), King (1977), Vandiver (1993) and Pantazopoulos (1994). Recently a new design guideline for free spanning pipelines have been issued by DNV (1997). The guideline provide design criteria and guidance on fatigue design methods for free spans subjected to combined wave and current loading.

Structural response modelling is used for determining the natural frequency of the free-span and the cyclic stress. The conventional approach is based on characterisation of an isolated free span modelled as a single span with simplified end conditions. The aim of the single span analysis is to define a maximum allowable free span length based on either onset of VIV or cumulative fatigue damage. This approach assumes that the dynamic behaviour of a span can be characterised by its length. The single span model have been refined in the HSE study (HSE, 1993) and the GUDESP project (Tura et al., 1994) where springs at the ends are introduced in an attempt to account for soil-pipe and span interaction.

In recent years the attention has been strongly focused on submarine pipelines crossing very uneven seabeds (Burattini et al., 1993, Damsgaard and Hermann, 1988, and Pulici, 1996). In these cases, the response of adjacent free spans can be interacting both statically and dynamically, making it difficult to describe the boundary conditions for each individual free-span. It has been argued that it becomes necessary to introduce a multispam model where a section of the line is modelled laying on the seabed profile with a distribution of free spans of different lengths along the line (Brusch, 1993, and Vitali, et al., 1993). The multispam method allows an accurate representation of the pipe deflection, effective force along the line and span interaction. An assessment based on a multispam analysis differ from the single span approach in that it allows the structural frequency for all spans to be assessed as a system and checked against the critical VIV frequency for each individual span. When using the conventional single span approach, each span is compared to a common critical span length.

This paper will review some of the variables effecting the structural modelling using both single span and multispam models. In the case of the multispam approach, full three dimensional analyses results for both a small (10") and large diameter (42") pipe are presented.

FINITE ELEMENT REPRESENTATION

When using structural modelling to determine the natural frequency of a span the following variables should be considered:

- Pipe structural properties
- In-place span configuration