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ScienceDirect

Procedia Engineering 199 (2017) 104–109

Procedia Engineering

www.elsevier.com/locate/procedia

X International Conference on Structural Dynamics, EURODYN 2017

The dynamic analysis of a steel pipeline under a seismic shock

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Abstract

This paper presents the analysis of the dynamic response of a steel overground pipeline to a strong seismic shock. The scientific motivation of this study was to identify the response of connections of steel pipeline sections to a strong seismic shock. A 105-metre-long steel pipeline was the subject of this investigation. A submodelling technique was used in the numerical analysis. All details, such as bolts, flanges and the support pillar, were modelled. Both models were subjected to non-uniform kinematic excitation. An actual seismic shock was used for the excitation of the pipeline. The excitation was applied to the structure as accelerations of particular supports acting in three dimensions. The three tested values of seismic wave velocity were 250m/s, 500m/s and 1500m/s; numerical calculation was conducted for each wave speed. During analyses, the normal stresses at representative points were calculated. The analysed points were located at the top, at the bottom and at the middle bolt. The values of stresses obtained for each analysis were compared. On the basis of this comparison, it can be noted that the stresses obtained for selected points reflected the complex state of stress in the connection. The bolt deformations also show the strong bending that occurred in connection elements.

Keywords: Pipeline; non-uniform excitation; flange connection; seismic analysis; submodel;

1. Introduction

The dynamic response of structures is necessary to analyse in the case of objects situated in areas affected by seismic activity. The calculations conducted for typical mid-sized and small structures do not tend to be problematic. Difficulties arise with large and complex objects with regard to lengthy numerical calculations and the analysis of structural details. Unfortunately, identifying the dynamic response of structural details is often a highly significant

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1877-7058 © 2017 The Authors. Published by Elsevier Ltd.
Peer-review under responsibility of the organizing committee of EURODYN 2017.
10.1016/j.proeng.2017.09.166

factor during analysis of the safety and resistant of a structure. The typical details which should be studied are element connections, bolts, welds, holes and other structural discontinuity [1,2].

Nowadays, 3D numerical models of structures, like steel halls [3], are usually created for dynamic analyses. However, particular members of steel halls are often modeled with beam elements. In such models details of connections are not modeled at all. In more precise analysis shell elements are used, e.g. to discretize steel webs and flanges in rolled section profiles of rafters and columns as well as details of connections. The scientific motivation of this study was to identify the response of connections of steel pipeline sections to a strong seismic shock.

In the paper the analysis of the dynamic response of an overground steel pipeline to a strong seismic shock is presented. The structural behaviour and the distribution of stress in the connections' bolts was calculated. The large size of the structure prevented making calculations with a density mesh; therefore, obtaining detailed results for small elements such as bolts was impossible [4]. To accelerate and increase the precision of calculations, the submodelling method was applied. The method allowed the analysis of the dynamic response of a bolted flange connection between two sections of the pipeline to an earthquake tremor without creating a detailed 3D model of the whole structure.

2. Basic parameters of the pipeline and flange connection

The dynamic response analysis presented in this paper was conducted for an overground steel gas pipeline. The analysed pipeline consists of seven fifteen-metre-long spans; the total length of the pipeline was 105m. This pipeline is representative of the particularly long structures that sometimes require dynamic analysis. The pipeline was supported by concrete pillars spaced at fifteen-metre intervals. The main pipeline consisted of a single, uncovered pipe with an exterior diameter of 0.6m. The thickness of the pipe was approximately 1.35cm. The pipeline was made of steel with a yield stress of 235MPa. As is typically the case when analysing objects of significant length, the connections between the different components the structure were also considered. The analysed connections were typical of those employed in this type of structure. These connections were bolted flange connections (see Fig. 1). The primary elements of the discussed joints were bolts and two flanges. The flanges were welded to the pipe envelope and linked together by a ring of twenty-four bolts. The bolts were located around the flanges. Bolts used in the connection were M30 bolts class 5.6 (yield stress 300MPa, resistant stress 500MPa).

The connections were located on each side of the fourth support. The connections were placed at a distant of 0.55m from the support axis.

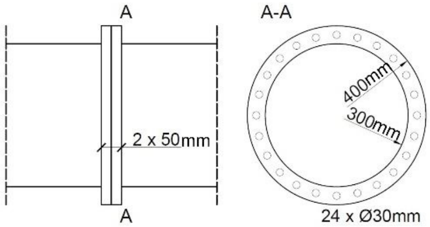

Fig. 1. Main dimensions of the bolted flange connection.

3. The numerical model of the pipeline

3.1. Submodeling technique – background information

To calculate the dynamic response of the steel pipeline, especially the response of the connections, the submodelling technique was used [5,6]. The submodelling technique allows us to study local, small parts of structures. It is not necessary to densify the mesh for whole elements in the analysis. Only a smart part of structures need to be remodelled. The submodel technique allow to combine two different finite element meshes. In this case, the detailed results for the chosen parts of the structures are obtained in a relatively short period of time, without the need for detailed calculations for the whole object.

The submodel analysis consists of several steps. The first stage is the creation of the global model, this represents the whole structure. Any simplifications which do not change the dynamic response of the structure are acceptable in