Engineering Structures 33 (2011) 2708–2715

Contents lists available at ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

Damage detection in elevated spherical containers partially filled with liquid

Oscar Curadelli *, Daniel Ambrosini

Engineering Faculty, Nacional University of Cuyo, CONICET, Centro Universitario - Parque Gral. San Martín - (5501) Mendoza, Argentina

ARTICLE INFO

Article history:
Received 12 October 2010
Received in revised form
23 May 2011
Accepted 24 May 2011
Available online 25 June 2011

Keywords:
Structural damage
Fluid–structure interaction
Spherical storage tanks
Dynamical properties

ABSTRACT

Damage detection through changes in the dynamic properties has received considerable attention in recent years. However, approaches in structures supporting tanks partially filled with liquid are scarce in the technical literature.

In this paper, a numerical–experimental study of damage detection in coupled fluid–structure elevated spherical tank systems is presented. The main objective is to investigate the feasibility to detect structural damage in the support structure by monitoring changes in natural frequencies. The major difficulty arises due to the changes in natural frequencies when the liquid level varies. Thus, in order to gain insight into the dynamical behaviour of the spherical containers and distinguish between the frequency shift caused by container filling conditions or by structural damage, experimental free vibration tests with small vibration amplitudes on a scaled spherical tank model are performed. The dependency of the identified frequencies on the structural damage severity is studied assuming three increasing levels of damage in the support structure. The results indicate that it is possible to detect structural damage, with acceptable confidence, up to liquid filling level of 30%. Moreover, only the "associated structural frequency" reflects the structural damage with a perceptible drop. Next, a numerical model of a real spherical container that takes into account the coupling between fluid and structure is presented to demonstrate the usefulness and validity of the results.

1. Introduction

Structural integrity and reliability are concerns for civil and industrial structures, especially for essential civil structures such as hospitals, emergency facilities, communication and operation centres, and critical components in petrochemical industries, refineries, and nuclear power plants. During its lifetime, the structural integrity condition of a component may be affected by natural degradation, aggressive environments and ambient factors (atmospheric corrosion, oxidation, erosion), and principally after exposure to exceptional events such as earthquakes. In these cases, structures might become damaged, and an early overall evaluation of their integrity is necessary in order to take pertinent and quick decisions to avoid failures or, eventually, collapse. From security and economic points of view, this initial diagnosis has significant consequences. For example, after an earthquake, it is important to determine the current serviceability of the affected structure to ensure safe operation in the present condition, and remaining service life; in the case of detecting small damage, the structure may be returned to an operational condition, so reducing the economic impact. These potential benefits, hence, justified the developing of methods for structural damage identification and led to the rapid growth of a research field known as structural health monitoring (SHM) [1].

According to the depth of diagnosis, the methods of damage identification may be classified into four levels [1].

- Level 1, Detection: Methods allow establishing if damage is present in the structure.
- Level 2, Location: Methods allow the location of the regions where damage occurred.
- Level 3, Quantification: Methods allow evaluating the intensity of damage.
- Level 4, Prediction: Methods allow predicting the remaining life of the structure.

Within level 1 of SHM, perhaps the most frequently used techniques, which have received considerable attention in recent literature, are global monitoring methods based on vibration measurements. The main advantage of global methods is that the measurement locations are not required to be close to damaged regions, (which, in general, are difficult to access), as required by local techniques. The basic idea springs from the notion that spectral properties, described in terms of the so-called modal parameters (frequencies, mode shapes, and modal damping), are functions of physical properties of the structure (mass, energy

* Corresponding address: Engineering Faculty, Nacional University of Cuyo, CONICET, Centro Universitario - Parque Gral. San Martín, Chaco 3688, Godoy Cruz (5547). Mendoza, Argentina. Tel.: +54 0261 4135000x2195; fax: +54 0261 4380120.
E-mail address: ocuradelli@fing.uncu.edu.ar (O. Curadelli).

0141-0296/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engstruct.2011.05.023