Journal of Constructional Steel Research 98 (2014) 178–187

Contents lists available at ScienceDirect

Journal of Constructional Steel Research

# Hybrid damping systems in offshore jacket platforms with float-over deck

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ARTICLE INFO

*Article history:*
Received 26 July 2012
Accepted 12 February 2014
Available online 22 April 2014

*Keywords:*
Offshore jacket platform
Wave-induced fatigue damage
Seismic load
Friction damper
Tuned mass damper
Hybrid damping system

ABSTRACT

Employing dampers to control wave-induced and seismic vibrations of offshore jacket platforms is an attractive method in order to mitigate fatigue and seismic damage. However, adjustable parameters of a damper are designed by considering only one type of environmental loads; either normal-condition load or extreme-condition load. So, it is important to investigate effectiveness of damping system, for both of two main categories of environmental loads. Also it is ideal for the system to have an acceptable performance in both normal and extreme conditions. The idea investigated in the current study is to use a friction damper device (FDD) and a tuned mass damper (TMD) simultaneously in offshore jacket platforms with float-over deck to control both fatigue damage as well as seismic vibration. To develop the idea, adjustable parameters of FDD and TMD have been adjusted for wave loading. Afterward, they are combined with those designed for earthquake, so the hybrid damping system (HDS) is introduced. By introducing HDS, it is intended to make damping system have a high seismic performance while being effective in fatigue damage mitigation. Moreover, HDS can have different combinations. So, certain variants of HDS are determined which have much higher performance than the other variants.



## 1. Introduction

Periodical inspections have demonstrated that offshore platforms in the Persian Gulf are highly vulnerable to fatigue damage during their operational life. Such investigations provide evidence that tubular members can experience significant damage including loss of cross sectional area, indicating that the fatigue damage should be considered more seriously in order to extend the operational life of offshore platforms. Nowadays, one third of the existing offshore platforms require life extension [1] and life extension process requires structural rehabilitation. Many researchers have put their focus on various methods for rehabilitating damaged or extra-loaded platforms and fatigue damage mitigation of offshore structures. Conventional rehabilitation methods can impose excessive cost of underwater welding and fabrication included in those processes, so a novel technology is proposed by researchers. This technology is to equip existing or even new offshore platforms with vibration control devices. Vibration control of offshore jacket platforms is very attractive because in general, reduction of the dynamic stress amplitude of an offshore structure by 15% can extend the service life over two times, and can result in decreasing the expenditure on the maintenance and inspection of the structure [2].

On the other hand, offshore platforms are of the economic life lines of oil-rich countries, so it is a serious problem on how to guarantee their immediate occupancy after earthquakes. Again, one proposed method to solve the problem is to employ vibration control devices. Some researchers have worked on this topic and have found it effective to use those devices to control seismic vibrations.

Among those who have studied vibration control of offshore platforms are Vincenzo and Roger [3], Ou et al. [4], Li et al. [5], Wang [6], Mahadik and Jangid [7], Zhou and Zhao [8], Patil and Jangid [9], Lee et al. [10], Ou et al. [2], Jin et al. [11], Ma et al. [12], Xu et al. [13], Yue et al. [14], Taflanidis et al. [15] and Kim [16]. All of them have found it effective to use control mechanisms for mitigation of vibrations induced by different environmental loads.

Recently, in some studies [17,18] adjustable parameters of one type of FDD have been optimized for realistic jacket platforms for wave-induced hydrodynamic loads. Moreover, Gholizad [19] has optimized TMD for use against wave-induced fatigue damage. Those works play a key role in the current study, since they are among several sources approached in order to obtain comprehensive data on the subject.

Offshore jacket platforms, located at severe environmental conditions, are generally subjected to two main categories of environmental loading, i.e. normal-condition loads such as wave-induced hydrodynamic force and extreme-condition loads like seismic excitation. The former external force has a significant contribution to fatigue damage which causes the excessive cost of rehabilitation and the latter one

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http://dx.doi.org/10.1016/j.jcsr.2014.02.004

can endanger the serviceability of offshore jacket platforms which are of the economic life lines of oil-rich countries.

Employing novel devices to control the wave-induced and seismic vibrations is an attractive method in order to mitigate fatigue damage and to guarantee immediate occupancy of offshore platforms after earthquakes. But, adjustable parameters of a vibration control system for offshore platforms are generally designed by considering only one type of environmental loading; either normal-condition load or extreme-condition load. So, it is important to investigate the effectiveness of vibration control system, for both of the two main categories of environmental loads.

The overall objective of this study is to investigate the idea of combining dampers with different designs to control both of two main categories of environmental loads exerted upon offshore platforms which are classified into normal-condition loads and extreme-condition loads. It is to be determined which combination of dampers is the most effective. So far, some other aspects of the idea of employing HDS in offshore jacket platforms have been discussed elsewhere in some papers [20,21].

## 2. Class of offshore platform under study

The jacket, the piles, and the deck are the main structural components of the offshore jacket platform. For topside installation, all deck facilities are fabricated into modules and then transported by barge and set on the platform by a derrick. Float-over decks are a development which enables the prefabrication of the complete topsides, so that it may be transported by barge and set as a complete unit on the preinstalled jacket [22]. With making use of float-over decks, some limitations are imposed over the characteristics of the platform. Float-over deck requires omission of bracings in one direction at the water surface level, in order to allow the barge to move between legs of the jacket and install the deck, so the stiffness of the platform at this level is very low compared to other levels.

Limitations of high flexibility of the upper elevation in one direction can be counteracted by making use of auxiliary vibration control devices.

In the current study, two realistic float-over-deck offshore jacket platforms shown in Fig. 1 are examined; "North Rankin B" (NRB) is a platform installed on Western Australia offshore oil fields with a height of 125 m and "Foroozan" (FRZ) is a six leg platform located in waters of the Persian Gulf with a height of 95 m. As their topsides have been installed with float-over technique, the bracings have been omitted in one direction at the water surface level. As a consequence, making use of auxiliary vibration control devices is a novel suggestion to counteract the effects of high flexibility at the upper levels of the jacket.

An idealized three-degree-of-freedom (3DOF) system (Fig. 2) is considered as the structural model for each platform. The values of lumped mass and pre-yielding stiffness have been determined by Golafshani and Gholizad [17] in a way that the overall model would have the same natural period and kinetic energy for each mode of vibration as the real overall platform. Some detailed descriptions of structural models, such as pre-yielding stiffness and lumped mass values, are listed in Table 1. In this table the $m_1$, $m_2$ and $m_3$ parameters are respectively the lumped mass of the first, second and third stories of the idealized 3DOF model of the platforms and the $k_1$, $k_2$ and $k_3$ parameters are respectively the stiffness of the first, second and third stories of the model. For each platform a proportional damping matrix is determined by considering the damping ratio for the first three modes of vibration to be 0.05, 0.03 and 0.02 [17].

## 3. Damping systems

### 3.1. FDD

FDD is a novel friction damper which can have many various models and configurations. It has been innovated by Mualla [23,24]. One simple configuration of FDD is shown in Fig. 3 This new damper device is based on friction between pad disks and steel plates. Simplicity of concept and

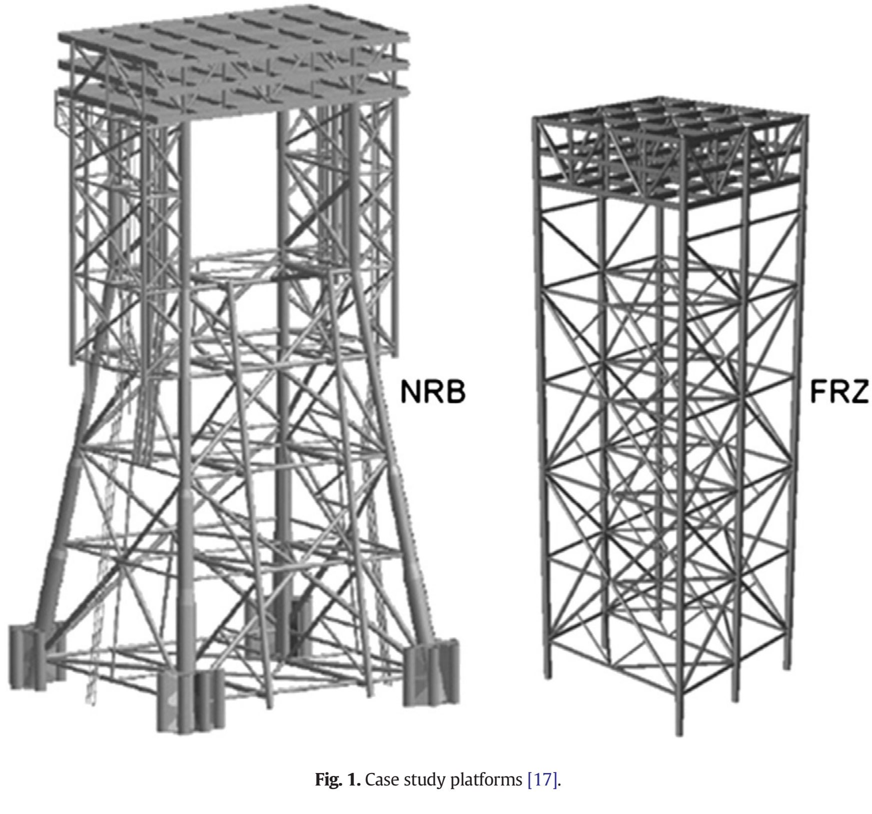


**Fig. 1.** Case study platforms [17].