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Passive control of offshore jacket platforms

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Abstract

The wave-induced dynamic force is one of the most important excitations to be dealt with in the design of offshore structures. In order to perform a reliable design of an offshore structure, it is important to obtain an exact evaluation of its dynamic response but also to examine the ways of reducing the response. This paper presents the response of offshore jacket platforms installed with energy dissipation devices such as viscoelastic, viscous and friction dampers under wave loading. The offshore jacket platforms are modeled as multi-degrees-of-freedom system provided with dampers at each floor location. The wave forces are modeled as per Morison's equation. The governing equations of motion of the jacket platform with dampers are derived and their solution in the frequency domain is presented. The uni-directional random wave loading is expressed by the Pierson-Muskowitz spectrum. The response of the jacket platform with viscoelastic, viscous and friction dampers is compared with the corresponding response without dampers in order to investigate the effectiveness of the passive control systems. It is observed that the additional dampers add substantial damping to structure and thus favorably control the response of platform structure. Among the various energy dissipation devices used for study, the viscoelastic dampers perform better in comparison to the other dampers. This is due to the fact that the added viscoelastic dampers contribute to increased viscous damping as well as lateral stiffness which reduces the response of the offshore jacket platforms significantly.

Keywords: Passive control; Hydrodynamic force; Jacket platform; Energy dissipation devices; Viscoelastic damper; Viscous damper; Friction damper

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1. Introduction

Among the various types of offshore structures, the steel jacket platform is the most common in use. Over the years, it has assumed a multi-functional role, being used for oil exploration, drilling as well as production. Conventionally, such platforms are built up to a depth of about 100–150 m, though some of them have exceeded 200 m (Chakrabarti, 1987). Usually, they are built from tubular steel members. These structures have a very low time period ranging between 2 and 8 s. An offshore structure such as a steel jacket platform apart from the operational loads also experiences environmental loads such as wind, wave and earthquake loads.

The safety of structures can usually be ensured by increasing their stiffness so as to shift the natural frequencies away from the resonating of frequencies. However, this approach is generally costly requiring excessive construction material. An alternate approach is to implement a passive and or active control mechanism to regulate the structural motion as desired (Soong, 1990). Passive control devices do not require external energy but they have a inherent limitation. On the other hand, an active control mechanism can be effective over a wide frequency range with the desired reduction in the dynamic response. The active control approach is now of current concern to many researchers and there are several attempts exploring its application to offshore structures. Kawano and Venkataramana (1992) and Kawano (1993) studied the response of offshore platforms with an active tuned mass damper installed and found that such mechanism is quite effective in reducing the response of platforms due to wave loading. Abdel-Rohman (1996) studied the application of certain active and passive control mechanisms to reduce the dynamic response of steel jacket platform due to wave-induced loading. Lee (1997) demonstrated the effectiveness of mechanical added dampers using stochastic analysis for offshore platform. Suneja and Datta (1998, 1999) demonstrated the effectiveness of an active control system for articulated leg platforms in view of minimizing the wave-induced response. Wang (2002) examined the effectiveness of the lateral vibration control for wave-excited response of offshore platforms with Magnetorheological dampers. Recently, Mahadik and Jangid (2003) studied the response of offshore jacket platforms with an active tuned mass damper under wave loading. Although, there had been several studies for effectiveness of the active and passive control mechanisms in controlling the response of offshore platforms under wave loading. However, very few studies are reported on the effectiveness of the passive control system with added dampers in controlling the response of offshore platforms under a parametric variation to study the influence of important system parameters and comparative performance of dampers.

This paper aims at developing passive control systems for vibration control of an offshore steel jacket platform using energy dissipation devices such as viscoelastic, viscous and friction dampers. The specific objectives of the study are: (i) to develop mathematical formulation for dynamic analysis of steel jacket platform with passive control system in the frequency domain; (ii) to investigate the effectiveness of passive control systems by comparing response of platforms in controlled and uncontrolled cases; (iii) to study the comparative performance of viscoelastic, viscous and friction dampers for vibration control of offshore jacket platforms; (iv) to find out optimal damping and stiffness coefficient of the viscoelastic dampers for minimum response of the jacket